Iron and Steel Engineer

Established 1907 as Proceedings of A. I. & S. E. E.

CONVENTION NUMBER

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Entered as second-class matter January 25th, 1924, at Pittsburgh, Pa., under the Act of March 3rd, 1879.
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Association of

IRON AND STEEL ELECTRICAL ENGINEERS

EXTEND A CORDIAL INVITATION
TO ATTEND THEIR

26th Annual Convention

AND

Iron and Steel Exposition

JUNE 16-17-18-19-20, 1930

HOTEL STATLER
BUFFALO, N. Y.

Technical Sessions 9:00 A. M. to 1:00 P. M.

Electrical Engineering Division

Combustion Engineering Division

Safety Engineering Division

Wire and Wire Products Division

EXPOSITION HOURS

Monday	1:30 to 5:30 P. M.	Evening 7:00 to 9:30 P. M.
Tuesday	1:30 to 5:30 P. M.	Evening not open
Wednesday	1:30 to 5:30 P. M.	Evening 7:00 to 9:30 P. M.
Thursday	1:30 to 5:30 P. M.	Evening not open
Friday	1:30 to 5:30 P. M.	Evening 7:00 to 9:30 P. M.

Iron and Steel Exposition, Broadway Auditorium, may be reached by taking, N. Y. C. Station busses at Public Square.

Association of Iron and Steel Electrical Engineers Convention *and* Iron and Steel Exposition

JUNE 16 - 17 - 18 - 19 - 20, 1930

Technical Sessions, ***Hotel Statler*** **BUFFALO, NEW YORK** **Iron and Steel Exposition,** ***Broadway Auditorium***

Convention and Iron and Steel Exposition Committees

General Convention Committee

F. O. SCHNURE, *General Convention Chairman*

W. E. Miller	A. C. Cummins	J. D. Donovan	R. F. Chaffin	W. N. Flanagan
M. H. Morgan	D. M. Petty	Wray Dudley	H. E. Davis	R. L. McIntosh
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V. I. Brinker	M. E. McGrail	J. A. Oartel	L. C. Edgar	F. D. Egan
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F. Acker	J. L. Hott	B. W. Gilson	A. L. Reichert	A. A. Stewart
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C. E. Miller	J. S. O'Donovan	R. S. Shoemaker	E. C. Marshall	S. E. McQuigg

General Registration Committee

J. H. VAN CAMPEN, *Chairman*

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R. L. Rapp	A. Proudfoot	O. H. Meineke	J. D. Scully	W. L. DeCoursey
A. W. Duncan	J. B. Crane	R. H. Ellis	R. C. Mohler	Myles Morgan

Monday Evening Informal Reception

C. S. PROUDFOOT, *Chairman*

A. L. Foell	R. W. Graham	O. W. Bodler	W. J. Harper	E. Coates
	F. G. Gasche	A. Proudfoot	F. S. Escott	

Invitation and Ticket Committee

A. L. FOELL, *Chairman*

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R. C. Boak	J. W. Jones	G. W. Black	J. A. Clauss	C. E. Bedell
A. E. Miller	G. A. Kaufman	Geo. H. McFeaters	S. Kneass	J. F. Hunter
J. Maloney	L. W. Galbraith	G. W. Baumgarten	H. F. Martin	Geo. H. Schaeffer
W. J. Donahue	A. W. Mohrman	P. F. Haberstick	D. W. McFayden	F. P. May

Iron and Steel Exposition Committee

W. S. HALL, *Chairman*

K. Raynor	H. C. Seibert	F. G. Cutler	C. H. Verwohlt	M. W. Cobbledick
E. Trexler	A. W. Steed	F. H. Kittredge	W. Reese	W. J. Harper
S. S. Wales	Geo. R. Roemer	W. E. Miller	F. L. Collins	F. A. Wiley
W. C. Suppler	Stanley H. McKee	S. N. Roberts	J. H. Van Campen	H. V. Flagg

Industrial Plant Visiting Committee

F. D. EGAN, *Chairman*

E. Coates R. W. Graham J. L. Hott A. L. Foell

Thursday Evening Formal Reception and Dinner Dance

F. W. CRAMER, *Chairman*

E. S. Newton	F. W. Jessop	G. L. Crosby	A. C. Garnett	F. D. Egan
A. J. Whitcomb	E. S. Sawtelle	E. H. Martindale	G. L. Stout	G. R. McDermott
H. E. Davis	K. H. Runkle	J. T. R. Bell	A. E. Tregenza	R. J. Harry
W. B. Connally	R. L. Brown	G. D. Mantle	A. J. Thompson	L. Ellman
A. J. Standing	A. C. Dyer	E. R. Lewis	J. S. Rowan	D. H. Tuck
Saul Lavine	W. E. Miller	J. R. Lewis	Roy M. Walker	C. J. Mundo
H. Fisher	J. E. Wood	R. F. Chaffin	D. E. Batesole	A. M. Ramsey
M. T. Maguire	F. F. Foss	N. C. Goin	H. W. Eastwood	S. Buckley
E. H. Younglove	F. H. Barnard	J. E. Sayer	W. H. Williams	H. S. Stockdale
J. Duff Reed	A. Kuhns	G. R. Thatcher	G. W. Hall	J. M. Kelly

ASSOCIATION OF IRON AND STEEL ELECTRICAL ENGINEERS

INSPECTION TRIP

LACKAWANNA PLANT

BETHLEHEM STEEL COMPANY LACKAWANNA, N. Y.

FRIDAY, JUNE 20th

Members, Guests and Exhibitors invited. Trip must be made in Special Busses which will leave the Main Entrance, Hotel Statler, Buffalo, N. Y. at 9:30 A. M. Reservations must be made for this trip at the Registration Desk, Main Lobby of the Hotel Statler, June 16, 17 and 18.

SCHEDULE AND ROUTE A. I. & S. E. E.
INSPECTION TRIP

9:30 A. M.—Leave Hotel Statler.
10:00 A. M.—Arrive at Plant.
10:15 A. M.—No. 2 Power House.
10:45 A. M.—Entrain.
10:50 A. M.—Blast Furnaces.
11:15 A. M.—Coke Oven Plant.
Complete Automatic Sub-Station.
11:45 A. M.—Entrain S. E. Coke Plant.
12:00 Noon—54" Blooming Mill Motor Room, No. 12 and No. 15 Mill Motor Rooms, No. 14 Mill 18", 14" Bar and Structural Mill.
1:00 P. M.—Luncheon (Guests of Mr. T. Burns, General Manager, Lackawanna Plant, Bethlehem Steel Company.)
1:30 P. M.—No. 5 Mill 48" Universal Plate Mill.
1:45 P. M.—No. 1 Open Hearth.
2:00 P. M.—No. 10 Mill 8", 10" Merchant Mill.
2:05 P. M.—No. 7 Mill Motor Room.
2:15 P. M.—No. 1 Rail Mill.
3:00 P. M.—Entrain.
3:15 P. M.—No. 3 Power House (Purchased Power Sub-Station.)
4:00 P. M.—Busses.
4:30 P. M.—Iron and Steel Exposition.

The Lackawanna Plant of the Bethlehem Steel Company is equipped to manufacture the following materials: Pig Iron, Ingots, Billets, Blooms, Slabs, Sheet Bars, Tie Plates, Heavy and Light Rails, Splice Bars, Structural Shapes, Sheared and Universal Plates, Merchant Bars, Concrete Reinforcing Bars, Sheet Piling and Fabricated Structural Material.

The steel and iron production equipment consists of 2 Open Hearth Plants, No. 1 Open Hearth has 14 100-ton stationary furnaces and No. 2 Open Hearth has 2 200-ton tilting and 8 100-ton stationary furnaces. Also, 4 10-ton converters. The capacity of the Open Hearth and Bessemer Departments are 2,000,000 gross tons per year. There are 7 blast furnaces, one of which is rated at 1,000 tons, 2 at 800 tons, one at 600 tons and 3 at 500 tons. The total capacity of Bessemer and Basic Pig Iron is 1,440,000 gross tons a year.

One of the high spots in the electrification of this plant is twelve reversing mill motors —one-eighth of the total reversing mill motors installed in the United States and Canada.

The total HP in reversing mill motors is 56,000.

List of Exhibitors at Iron and Steel Exposition

BROADWAY AUDITORIUM BUFFALO, N. Y.

JUNE 16 - 17 - 18 - 19 - 20, 1930

Exhibitor	Booth No.
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American Engineering Company	5
American Manganese Bronze Co.	198-199
Appleton Electric Company	103-104
Atlas Car & Manufacturing Co.	25-26-27
Automatic Reclosing Circuit Breaker Company	7
Bailey Meter Company	163
Baker-Raulang Company	177-197
Bartlett-Hayward Company	154
Benjamin Electric Co.	63-64
Botfield Refractories Co.	178
Bristol Company	56-57
Brown Instrument Company	78
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Clarage Fan Company	127
Clark Controller Company	86-87-106-107
Cleveland Crane & Engrg. Co.	75-76
Cleveland Worm & Gear Co.	164
Cling-Surface Company	98
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Condit Electric Mfg. Company	46
Crocker-Wheeler Electric Mfg. Company	91-111
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Delta Star Electric Co.	45
M. H. Detrick Company	30
Joseph Dixon Crucible Co.	38
Door Burner Corporation	144
Edison Storage Battery Co.	137
Electric Controller & Mfg. Co.	49-50-69-70
Electrical Engineers Equipment Co.	185
Electric Machinery Mfg. Co.	88-108
Electric Power Equipment Corp.	84
Electric Service Supplies Co.	55
Electric Storage Battery Co.	143
Electro Dynamic Company	290
Erie Malleable Iron Co.	114
Erie Steel Construction Co.	1
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Hyatt Roller Bearing Co.	136-156
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Lapp Insulator Company	133-153
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Moloney Electric Company	133-153
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Morgan Engineering Co.	149-150
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National Carbon Company	128
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Pyle-National Company	28-29
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Republic Flow Meters Co.	165
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Transmission Ball Bearing Co.	39
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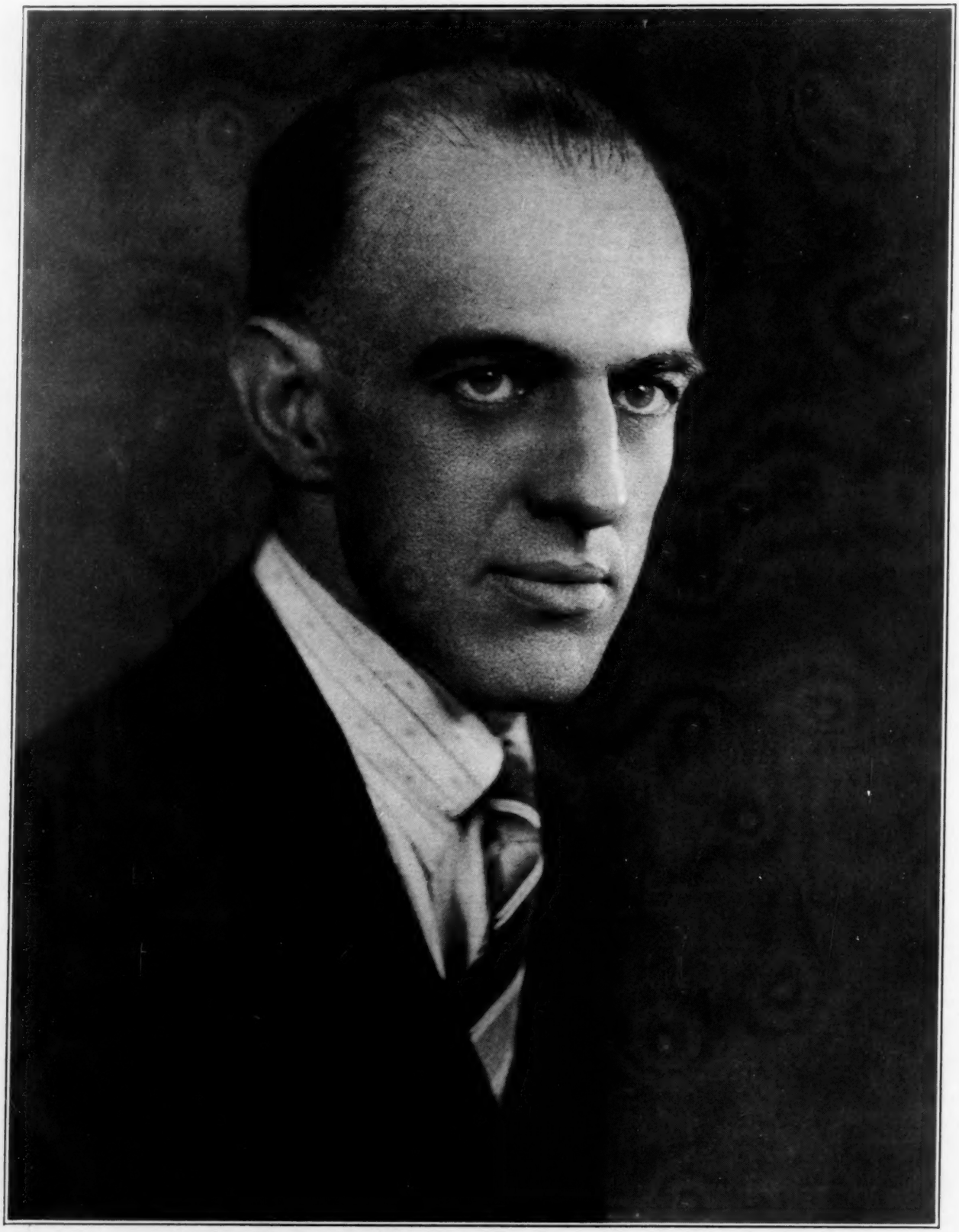

Mr. F. W. Cramer, Chief Electrical Engineer of the Republic Iron and Steel Company, Youngstown, Ohio, President of the Association of Iron & Steel Electrical Engineers for the year 1929-1930.

Twenty-sixth Annual Convention and Iron and Steel Exposition

By F. W. CRAMER*

Another year has passed into history and the time for taking an inventory of accomplishments is at hand. In many respects the past year has been very similar to many others in the history of our organization. The membership has been increased, the publication has expanded and the attendance at many of our meetings surpassed our fondest expectations. Since these expansions occur each succeeding year, there must be something real back of our organization to bring about this ever increasing amount of success.

Ten years ago we were wondering how soon the available subjects to write about and discuss would be covered. Today, thanks to the multiplicity of electrical applications, we are faced with just the reverse of this problem and have to select the subjects and material to be used. It is also interesting to note that many of the subjects so ably discussed and apparently decided in the early days of our organization are more active and interesting in present day applications than they ever were in the past. Motors, Cranes, Brushes, Bearings and those allied parts that really form the basis of the art are given more detailed thought than ever before. Perhaps this is one of the indications that the modern successful Steel Mill Electrical Engineer is progressive, never satisfied with existing equipment and convinced that perfection has not been reached with any equipment on the market. As a result we have the happy combination of one group who want something better and who are willing to try new ideas and another group of progressive Electrical Manufacturers who try to fulfill their desires.

Each year we build the last word in Rolling Mills, but the record is short lived. Each year a new process or perhaps several of them appear that sentence many of the "last word" mills to the scrap pile. With these new mills comes more speed and more power until it has long been necessary to remove the actual functioning of the apparatus from human manipulation and gives the operator only a small master switch or push button which in turn allows the automatic control to perform the actual operation. At present there does not seem to be any apparent limit of what can be accomplished with automatic electrical equipments in the production of steel.

With a foundation such as this and a future filled with innumerable possibilities, it is little wonder why one of the really big tasks in preparing the convention program was to find sufficient time for the rendition of the papers that were prepared.

It is not my purpose to give in detail the technical program of the convention, but there are several unusual and outstanding papers that should have your attention.

The paper on "Should Colleges and Universities Adopt a Safety Engineers Course in their Curriculum," presents a new thought in the great safety movement and has already created a lot of discussion. We are all anxious to hear the comments that will be given regarding this idea.

"The Theory of Rolling of Plastic Materials" by Mr. Gasche is one of the most unusual contributions ever made to our organization. This information will be the textbook for power drive requirements in the steel industry and our Association is exceedingly fortunate to have this paper presented at the annual convention.

Two other familiar subjects, Cranes and Antifriction Bearings will be presented and with the vast amount of information and experience available promise to bring forth the most spirited discussions of the week.

A new branch of activity this year, which will run an entirely separate program is the "Wire and Wire Products Division." In their exhibition actual wire drawing will take place.

For the occasion of our Annual Banquet, we have secured one of the most gifted and interesting speakers in the country—the Congresswoman from Florida, Mrs. Ruth Bryan Owen. Her message on "Opening Doors" will long be remembered by all those fortunate enough to be present for this occasion.

We are going to have a wonderful convention—50,000 square feet of exhibits, more technical papers than ever before, a Ladies Program, and the most successful banquet in our history—and it will be held in a City that is eager to welcome us. So the Kelly Motto of "Bigger and Better than Ever" will hold good again in Buffalo.

After this what of the future? During the coming year the key meetings of the sections should be better attended than ever before. If it is possible to get 700 people in Youngstown and 1,000 in Cleveland, —then Pittsburgh, Chicago and Philadelphia should be able to exceed these records. There never has been a time in the history of our organization when the immediate future promised so much of interest to the Steel Mill Electrical Engineers. The officers for the coming year are aware of these facts and with the ever increasing support given by the membership, the meetings during the coming year should be the most successful ever held.

* President of Association of Iron & Steel Electrical Engineers and Chief Electrical Engineer, Republic Iron & Steel Co., Youngstown, Ohio.

Monday, June 16th

9:00 A.M. Registration, Main Lobby, Hotel Statler Chairman J. H. Van Campen, Chief Engineer, Republic Iron & Steel Company, Trumbull Plant, Warren, Ohio.

9:30 A.M. Business Session, Membership invited; The Major Ball Room, Main Lobby. Chairman, F. W. Cramer, Chief Electrical Engineer, Republic Steel Corp., Youngstown, Ohio.

Technical Sessions
Electrical Engineering Division

Major Ball Room, Main Lobby Floor, Hotel Statler

General Chairman, W. E. Miller, Electrical Supt., Bethlehem Steel Company, Johnstown, Pa. Secretary, C. M. Meyers, Assistant Electrical Engineer, Youngstown Sheet & Tube Company, Youngstown, Ohio.

9:45 A.M. "Electrical Developments in the Iron and Steel Industry," by Walter H. Burr, Electrical Superintendent, Lukens Steel Company, Coatesville, Pa.

10:15 A.M. "Shop Practices in the Iron and Steel Industry," by J. J. Booth, Electrical Superintendent, National Tube Company, Gary, Ind.

11:00 A.M. "Steel Mill Lighting Problems," by R. F. Sanner, Assistant to the Electrical Engineer, Carnegie Steel Company, Duquesne, Pa.

12:30 P.M. Informal Luncheon, Major Ball Room, Main Lobby. *Members, Guests and Exhibitors invited.*

1:15 P.M. "Industrialization in the U.S.S.R. by Gordon Fox, Electrical Engineer, Freyn Engineering Company, Chicago, Illinois. (Mr. Fox has just returned from a trip from the U.S.S.R.)

Safety Engineering Division

Major Ball Room, Main Lobby Floor, Hotel Statler

General Chairman, C. L. Baker, Management's Representative, Bethlehem Steel Company, Lackawanna, N. Y. Secretary, J. D. Donovan, Superintendent, Mechanical and Electrical Departments, Central Alloy Division of Republic Steel Corporation, Massillon, Ohio.

1:45 P.M. "Should Universities and Colleges Establish a Safety Engineering Course in their Curriculum," by J. A. Voss, Central Alloy Division of Republic Steel Corporation, Massillon, O.

Official Opening of the Iron and Steel Exposition

7:00 P.M. Broadway Auditorium.

Take N. Y. C. Station Busses at Public Square.

50,000 square feet devoted to Industrial Exhibits. More Steel Mill Equipment in Operation than all other Shows in America combined.

Informal Reception

Major Ball Room, Main Lobby Floor, Hotel Statler

9:00 P.M. Chairman, C. S. Proudfoot, General Manager, Vanadium Corp. of America, Niagara Falls, N. Y. Features, Entertainment and Dancing. *Members, Guests and Exhibitors particularly invited.* Come and get acquainted with the Iron and Steel Industry. Member's Registration Cards and Exhibitor's Passes Admit.

Official

CONVENTION AND IRON

AUSP

Association of Iron and

JUNE 16-17-18

HOTEL S

BUFFA

Tuesday, June 17th

TECHNICAL SESSIONS

ELECTRICAL AND COMBUSTION ENGINEERING DIVISIONS

Major Ball Room, Main Lobby Floor, Hotel Statler

General Chairman, R. S. Shoemaker, Superintendent of Rolling Mills, American Rolling Mill Company, Middletown, O. Secretary, J. H. Van Campen, Chief Engineer, Republic Steel Corporation, Trumbull Works, Warren, O.

9:30 A.M. "The Theory of Rolling of Plastic Materials" by F. G. Gasche, Combustion Engineer, Bethlehem Steel Company, Lackawanna, N. Y. Discussion: "A Rolling Mill Analysis," by E. Kieft, Engineer of Tests, Illinois Steel Co., Gary, Indiana.

ELECTRICAL ENGINEERING DIVISION

Major Ball Room, Main Lobby Floor, Hotel Statler

Chairman, S. S. Wales, Chief Electrical Engineer, Carnegie Steel Company, Pittsburgh, Pa. Secretary John C. Reed, Bethlehem Steel Company, Steelton Plant, Steelton, Pa.

11:00 A.M. "Applying the Principles of Steel Mill Practice to Arc Welding," by J. B. Austin, Research Engineer, Una Welding and Bonding Company, Cleveland, Ohio.

12:30 P.M. Luncheon, Major Ball Room, Main Floor Lobby; *Membership, Guests and Exhibitors Invited.*

1:15 P.M. "Installation of Electric Skip Hoist, Bell Hoist and Stock Line Recorder at the Anzan Steel Works, South Manchuria China," by Frank Smith, Otis Elevator Company, Pittsburgh, Pa.

1:45 P.M. A Moving Picture, "From the Raw Materials to the Finished Product," by George Richardson, Bethlehem Steel Co., Bethlehem, Pa.

Combustion Engineering Division

Parlor B, Mezzanine Floor, Hotel Statler

General Chairman, Martin J. Conway, Combustion Engineer, Lukens Steel Company, Coatesville, Pa. Secretary, Walter N. Flanagan, Special Engineer, Carnegie Steel Company, Pittsburgh, Pa.

11:00 A.M. "Recent Developments in Industrial Furnace Design," by G. R. McDermott, Vice President and General Manager, The Chapman Stein Company, Mt. Vernon, Ohio.

Chairman, F. E. Leahy, Combustion Engineer, Youngstown Sheet & Tube Company, Youngstown, Ohio. Secretary, H. V. Flagg, Assistant Combustion

Program

AND STEEL EXPOSITION

ICES

Steel Electrical Engineers

-19-20, 1930

TATLER

LO, N. Y.

Engineer, American Rolling Mill Company, Middletown, Ohio.

2:15 P.M. "Symposium Open Hearth Furnace Control," by R. W. Simpson of The American Heat Economy Bureau, Pittsburgh, Pa., and Joseph F. Shadgen, Smoot Engineering Co., New York, N. Y., and representatives from Shallcross Controls Systems Co., Bailey Meter Co., Leeds and Northrup Co., and Republic Flow Meters Co., Morgan Construction Co., Brown Instrument Co., Bristol Co.

Tuesday Afternoon

1:00 P.M. A. I. & S. E. E. Ladies' Bridge Luncheon. Hotel Statler.

Wednesday, June 18th

TECHNICAL SESSIONS

ELECTRICAL ENGINEERING DIVISION

Major Ball Room, Main Lobby Floor, Hotel Statler

General Chairman, J. H. Van Campen, Chief Engineer, Republic Steel Corporation, Warren, Ohio, Secretary, Wray Dudley, Electrical Engineer, National Tube Co., Pittsburgh, Pa.

9:30 A.M. Anti-Friction Bearings for Mill Type Motors, General Purpose Motors, Electrical Overhead Traveling Cranes, by Special Committee on Bearings. F. D. Egan, Chairman, Electrical Superintendent, Bethlehem Steel Company, Lackawanna, N. Y.
Special Feature. Anti-Friction Bearings for Roll Necks to be discussed by Steel Mill Executives, Engineers and Anti-Friction Bearing Manufacturers.

Combustion Engineering Division

8:00 A.M. Inspection Trip to Plant of Steel Company of Canada for Combustion Engineers only. Details later. Discussion after Inspection Trip, "The Use of Mixed Gases in Steel Plants."

Wire and Wire Products Division

Iroquois Room, Mezzanine Floor, Hotel Statler

9:30 A.M. "Galvanizing," by W. H. Spowers, Jr., Consulting Galvanizing Engineer, New York.

10:15 A.M. "Methods of Drawing Rods" (Observations of a European Rod Drawing Process as observed on a trip just completed through European Wire Mills), by Kenneth Lewis, Vice President, Morgan Construction Company, Worcester, Mass.

11:30 A.M. "The Latest Developments in Wire Drawing, Wire Forming Machinery and Equipment," by C. S. Arms, Consulting Engineer, Sleeper & Hartley, Inc., Worcester, Mass.
A moving picture—"The Making of Steel Wire," by American Steel & Wire Company, Cleveland, Ohio.
A moving picture,—"The Story of Monel Metal," by the International Nickel Company, New York, N. Y.

A. I. & S. E. E. Ladies' Luncheon

10:00 A.M. Trip to the Roycrofters. Leave main entrance Statler Hotel, in special busses. Luncheon at 12 o'clock at the Roycroft Inn, East Aurora, N. Y. Inspection of Roycrofters Shop at 1:00 P.M. Return at 3:30 P.M.

Thursday, June 19th

Electrical Engineering Division

Major Ball Room, Main Lobby Floor, Hotel Statler

General Chairman, J. J. Booth, Electrical Superintendent, National Tube Company, Gary, Indiana. Secretary, A. A. Stewart, Electrical Superintendent, Pittsburgh Steel Company, Monessen, Pa.

9:30 A.M. "A Discussion of the Proposed Amended A. I. & S. E. E. Specifications Covering Electric Overhead Traveling Cranes," by Executives, Engineers of the Iron and Steel Industry and the Crane Builders of the United States.

Chairman, A. J. Standing, Electrical Superintendent, Bethlehem Steel Company, Saucon Plant, Bethlehem, Pa. Secretary, Norman C. Bye, Chief Engineer, Henry L. Disston's Sons, Inc., Philadelphia, Pa.

11:00 A.M. "Electrical Installations at the Lackawanna Plant of the Bethlehem Steel Company," by F. D. Egan, Electrical Superintendent, Lackawanna Plant, Lackawanna, N. Y.

FORMAL RECEPTION AND DINNER DANCE

Major Ball Room, Main Lobby Floor, Hotel Statler

Featuring: MRS. RUTH BRYAN OWEN

Member of United States House of Representatives Fourth District, Florida

General Chairman, F. W. Cramer, President, Association of Iron and Steel Electrical Engineers. *Members, Guests, Exhibitors Invited.* Tickets may be secured at Registration Desk, Main Lobby.

Friday, June 20th

INSPECTION TRIP

Bethlehem Steel Co., Lackawanna Plant, Lackawanna, N.Y.

All Engineering Divisions, Guests and Exhibitors Invited

Trip will be made in special busses which will leave the main entrance of the Hotel Statler, Buffalo, N. Y., at 9:30 A.M. Reservations must be made for this trip at the Registration Desk in the Main Lobby of the Hotel Statler or at the Official Headquarters of the Iron and Steel Exposition at the Broadway Auditorium.

A. I. & S. E. E. Ladies' Niagara Falls Trip

10:00 A.M. Leave Main Entrance, Hotel Statler in special busses. Tickets, $2.00. May be obtained at Registration Desk, Main Lobby, Hotel Statler.

Engineers, Economics and Economies

By FEODORE F. FOSS*

In his prophetic work "The Decline of the West," Oswald Spengler pays tribute to the technic of our age, and says in substance the following: "Rationalism simultaneously with the discovery of steam engine has upset everything in eighteenth century and has transformed economic life from the foundation up, creating the idea of the Machine—as a small Cosmos which is obedient to the man . . . For the sake of the Machine human life becomes precious." "**Work** becomes the great word of ethical thinking, in the eighteenth century it loses its derogatory implication in all languages. The Machine works and forces the man to co-operate" . . . "Although socialistic theory of the present day has insisted upon looking only at the workman's contribution and has

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claimed the word 'work' for him alone—it has all become possible only through the sovereign and decisive achievement of the entrepreneur."

"The center of the artificial and complicated realm of the Machine is the organizer and manager. The mind, not the hand, holds it together. It is a figure that is apt to be forgotten in this conflict of politics —the engineer—the priest of the Machine—the man who knows it."

"Not merely the importance but the very existence of the industry depends on the existence of the hundreds of thousands talented, rigorously schooled brains that command the technic and develop it onward and onward."

Very little can be added to this conclusion in which Spengler puts the engineer at the head of the national economic life. In these words he has expressed what most of us know and feel, although in our relations with practical life we engineers do not place ourselves as high as Spengler does.

Engineers do not speculate whether collectively they are as omnipotent as represented by the most prominent of the present day philosophers. In the meantime, however, engineers fully understand their responsibilities toward humanity and realize their position in the world.

Adam Smith has classified factors in production of wealth as "Nature, Capital and Work." John Bates Clark recognizes but two factors of production in static industry which he names as "landlord and labor." He retains, however, the entrepreneur as a residual claimant of the results of the dynamic changes.

The reason why these great economists did not emphasize the role engineer plays in the economic life, can be found in the fact that in their time economic life was more static than dynamic. Preponderence of the dynamic conditions in our present life is that what actually changes modern conception of the factors of progress.

More modern economists already distinguish four factors and four shares in the products of industry. Conditions of our present industrial life, however, are so enormously influenced by sweeping inventions of the engineer that we have to await arrival of a new school of economists which will completely change the classification of production and progress factors, and will put the creative engineer in the place where he actually belongs.

With modern understanding of economic elements, we encounter the engineer as creator and producer in every branch of our economic life—agriculture and forestry, mining and manufacturing, trading, transportation and communication. Every branch of our life reflects the influence of engineering activities.

Wherever we go, whatever we see and use—we find that responsibility for the past progress and influence on the future achievements of our economic life rests with the engineer and his work.

This fact defines the position of the engineer, describes his duties and brings up to him clear understanding of the degree of mental preparedness and scientific equipment he should have to be able to bear such responsibility.

The purpose of our daily work is to give to society the largest possible amount of products for the smallest possible compensation from its part, to create, so to speak, maximum of common good with least efforts. With such definition of the productive work it is again easy to visualize what engineering activities should be.

These activities cannot be purely technical, they must be economical as well.

Whether the engineer helps to reap the harvest of the soil, dig minerals from underground, erect buildings or construct a machine and electrical motor, conduct a chemical process—his creative force is measured by the results of production, which in their turn are represented by the cost of the product.

Not a long time ago the principal requirement of an engineer, when constructing a machine or erecting a building, was to calculate the stresses in the machine, stability of building's elements, safe working

*Assistant to the President, Wheeling Steel Corporation, Wheeling, W. Va.

of this or that, and his activities practically stopped at that. Now—in the age of acute competition not only among different industrial concerns but among different groups of industries, among nations and even among different powers of Nature—old requirements of an engineer are far from being enough. Unless he calculates with the same degree of preciseness, which he uses in determining stresses in a machine or building, the profitableness of this building or machine—his work is not complete.

The prerequisites of an engineer of today is his efficiency with which he solves technical and economical problems at the same time. It is not the question any more, whether the machine or an appliance will work and perform this or that function, the main point is **"what is the economic efficiency** of this machine or structure, and what is its profitableness?" Efficiency in economic results is the criterion of every engineering creation nowadays.

Every human enterprise is based on figures, which represent economic efficiency of every movement. Figures stay, so to speak, on guard of this efficiency and this guarding of economic side of human activities is accomplished by the group of mathematical disciplines which are called "general accounting," "cost accounting" and "statistics." These disciplines work not separately from each other—they are very closely interconnected and supplement each other in many ways.

How much broader will the engineer understand his problems, and how much easier will he follow causes of waste in his practical branch of operation; how much easier will he be able to evaluate every detail in a complex entity of his work if he systematically resorts to the figures of cost? That is an axiom. Saying this seems to be repeating platitudes, but if we turn to the actual performance of our every-day engineering practice we find that these axioms are not always before the eyes of many engineers in industry as a whole, and in many industrial concerns in particular.

If it is rather difficult nowadays to find a technical man who does not recognize the importance of economics in his business, it is easy to find men who do not pay enough attention to the principles of accounting and to its findings.

It is a well-known story about one superintendent who called accounting in his plant "bunkum" because of charging the coal used for heating of office buildings into "overhead expense." "Coal is fuel and should appear in 'fuel' item and not in the 'overhead expense,' which is 'management,'" said he.

Overhead expense belongs also to the problems which even at the present time are hardly understood by many engineers. The role these expenses play in cost of production, however, deserves most detailed attention of engineers, as by regulating them in connection with "tonnage" and "time involved," the engineer may achieve wonders in costs.

How many of us have before our eyes this hyperbolic curve which represents changing costs, and which under proper management has a tendency to come closer and closer to its asymptote?

There is, of course, another side to this point, as some engineers in arduous endeavor to establish low cost of production lose money, efforts and time by attempting to bring this curve too close to the asymptote. They lose sight of the fact that there is always a certain point of the curve where an equilibrium of effort and result entails. Beyond this point there is no practical gain and the results achieved will not be worthy of effort. They forget the Jevons formula on final degree of utility, which says that "the utility of final increment of commodity is less than that of every other increment." Sometimes this expression is mixed with Ricardian law of "diminishing returns," which is based on land economics and practically has no application in manufacturing conditions.

There is also an example of long standing, which illustrates limits of engineering efforts in certain economic conditions. Everybody visiting Egypt sees that the largest part of peasants' land is irrigated by the so-called "shadoofs"—crudely made counterpoised sweeps, on one end of which is a semblance of a bucket made out of a piece of leather, tied to the rope on four points. These shadoofs stand on the banks of the river, sometimes three—one above another—on a steep bank, and are operated by a boy who raises water from the Nile to the reservoirs. The whole procedure is so rough and so uneconomical at a glance, that every visitor exclaims "Is it not a shame on the engineering profession?" That was said fifty years ago and is repeated every year since; the fellaheen boys, nevertheless, still do their shadoofing and will do that until economic civilization of Egypt will change.

The reason for that can be found in the point of economic equilibrium on the curve representing cost of irrigation in this locality. The boy gets 15 cents a day, raises 30,000 gallons of water in a daytime, capital invested for this mechanical arrangement being practically nil.

Such conflicting examples can be found not only in Egypt; they are with us every day in different form and size, and it takes real engineering sense to clearly understand such problems under our circumstances and solve them without incurring much expense.

Engineer's economic sense is needed to keep in balance conflicting extremes: total lack of economic consideration in production on one side, and on the other—ineffective spending of money and efforts in the endeavor of bringing highest possible technical results.

Which sin is greater—is difficult to say; both of them, however, can be avoided by constant keeping the right proportion between "utility" and "value."

Every technical problem of our day is a mathematical problem with the element of cost persistently present in it. Therefore, spirit of economic calculation, cost accounting frame of mind—should be always with the modern engineer, who must be accustomed to think in terms of economics. That is his duty towards betterment of industrial competition, production and employment.

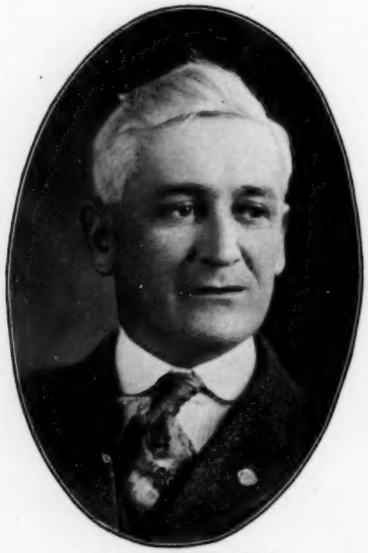
Future Thoughts in Fuel Economy

By J. D. DONOVAN*

A survey of the continuous panorama of world history reveals a periodic repetition of the rise and fall of nations. It is often said that history repeats itself, and the cyclic replacement of old nations, old cultures, old institutions, old ideas by the new, bears eloquent testimony to the statement.

If we investigate further it is not difficult to locate the major cause for this action. Paralleling every decline in the success and prestige of an institution we find a similar depletion in its resources. The chief resource of the ancient Greek and Roman civilizations was their man power, and as it wasted away, their grandeur was dimmed by conquerors having superior resources, again in the form of vigorous, agressive man power.

A comparatively short period of research and invention has brought us to a machine age, and with its



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advent, man power has ceased to be the all-important asset of a country, though still a major one. Other elements must now be listed among resources to be conserved, and, as the result of our constant research and development, this list is steadily increasing.

The longer and more exhaustive this list grows, the more important becomes the question of conservation, and the more stress must be laid upon its practice. Perhaps the most important part we can take in this practice is to adopt for ourselves, and to foster among our associates and employes, a spirit of "contented discontent." Paradoxical though this may sound, it is the frame of mind that will produce efficient work and good results. While it is true that a contented man is a good workman, this content must not spread to the point where we are satisfied with everything and allow ourselves to get into a rut, following the groove as the path of least resistance. Rather must we practice and encourage an attitude of discontent with present methods and strive constantly for improvement. Let our methods and our work be open at all times to sound, constructive criticism, otherwise improvement is extremely unlikely and progress is stifled. The attitude of "contented discontent" therefore throws open the doors and paves the way for changes in methods and processes which will aid in the work of conservation.

The activities of the Association of Iron & Steel Electrical Engineers are intimately allied with the practice of conservation. The Association's daily work is an unceasing effort to eliminate waste. In our maintenance work we seek to prevent waste of material. The Safety Division aims to preserve human life and limb. In this line they have been pioneers and can look back over our work with a degree of satisfaction. Perhaps their greatest opportunity for the future in the work of conservation lies in the utilization of fuel, which is one of the most important resources in our national and industrial life.

American industrial efficiency is famous the world over and in fact is the basis for our wealth as a nation, which is without equal in all the world's history. Yet we have a long way to go before becoming truly efficient and the use of fuels is one department of our industrial machinery which does not bear very close inspection. Natural fuels are present in such abundance in this country that their use has not received the intensive study which goes hand in hand with limited supply. We have always been recklessly wasteful of our natural resources.

Great savings have been made in fuel consumption in the past. The old bee-hive coking, with a latent thermal output of only about 70% of the heat in the coal charged, has been largely replaced by by-product coking, with a thermal efficiency of about 90%. On figures given by the U. S. Bureau of Mines, showing an annual total of about 85,000,000 tons of coal coked in the United States, this would mean a saving of the equivalent of 17,000,000 tons of coal per year, to say nothing of the higher monetary value of the by-products. We have heard and discussed papers concerning the salvaging of the sensible heat in the coke discharge from the oven. This procedure will result in an additional saving of 2 to 3%.

Efficiency in the use of Blast Furnace Gas has been raised from around 50% to 75 or 80% by means of adequate burner equipment and improved efficiency both in Hot Blast Stoves and Boiler design. There is still a 5 to 6% loss in sensible heat due to the wet washing method of cleaning this gas. The use of hot metal in the Open Hearth has been extended, and open hearth furnace design has gradually changed, with constant reduction in fuel rates. Waste heat boiler application is almost universal. Straight line mill production has cut down the amount of reheating necessary, and improved furnace design, tending to develop along continuous lines, has cut the heat expenditure. Even to the Sheet Mill furnaces has this idea of continuous heating spread, where it is establishing enviable records of economy.

* Supt. Mech. & Elec. Depts., Central Alloy Division, Republic Steel Corporation.

The use of heat insulation is becoming more general, and we find as much as 13½ inches of insulation on furnaces operating at temperatures as low as 1400° F.

It is now possible for a complete balanced steel plant unit, producing no finished, semi-finished or special products, to operate entirely on the coal charged into the coke ovens, with no additional fuel for heating or power generation. The majority of our plants do not fall into this classification, due to the common prevalence of semi-finished products, and, what is regrettably more common, to the fact that our fuel prices are so low that we cannot justify the installation expense of heat saving equipment. Europe, with its cheap labor and expensive fuel, has developed heat economy much farther than we have and can show us a few tricks in fuel economy. It is an ill effect of the economic principles of price regulation by supply and demand that we are permitted to waste our national resources until the supply is curtailed.

In the generation of electric power increased economies have also been effected. It was not until the electrical industry started its great program of scientific research that it became possible to secure as much electric current from one pound of coal as had formerly been obtainable from three. Combustion equipment and methods have been doubled in efficiency as a result. Hence, in spite of America's amazing industrial growth, the amount of coal needed to sustain this rapid advance of industry and commerce was no greater than before. The increasing size of individual plants has made possible the installation of larger generating units. Turbo-Generators are now installed in steel plants up to 20,000 KW capacity, and boilers have kept in step, running as high as 2,000 H.P. The increased efficiency of these larger units and the better control made possible by their centralization have materially decreased the heat consumption, so that a K.W.H. can be produced on about 15,000 B.T.U. Higher steam pressure has also been a contributing factor to this end. With pressures scattered over the entire range up to 1,800 lbs., data will be available to aid in the choice of the most economical pressure. At the present time it is the concensus of opinion that about 450 lbs. is to be preferred, although the load factor of a plant has a decided influence on the selection; a high load factor enabling the increased operating efficiency of the high pressure plant to offset the higher investment charges.

Another phase of power utilization offering possibilities of economy is that of inter-connection of the industrial power plant with the public utility, with an interchange of power agreement. This idea seems to be gaining more and more favor, and there is no reason why such arrangements cannot prove of mutual benefit to both the industry and the utility. The necessity of stand-by equipment is materially lessened. The various by-products, such as coke gas, blast furnace gas, coke breeze, tar, waste heat, etc., must be used. At off-peak loads, the exchange of power with the utility system affords a convenient and economical outlet for these by-products, while simultaneously furnishing power to the utility at a rate lower than their cost of generation and distribution. The diversity resulting from a widespread adoption of this policy would also give the utility added capacity without actual enlargement of their system.

While we have attempted in this article to give some idea of our fuel problem and to point out the savings possible through fuel economy, we do not mean to imply that the subject of fuel is not receiving serious thought. The present era of high steam pressures and high temperatures, of rapid combustion and high rates of evaporation, has been made possible by the combined efforts of the technical engineer, the physicist, the metallurgist and the chemist. These men have first defined theory and have then translated that theory into sound practice. We plant operators should familiarize ourselves with these new tools which science has made available to us; for our advancement as individuals must surely lie in the same direction as the trend of progress in our field of work. It too is a wise executive who recognizes the value of research and who encourages its application as a means of raising existing standards.

We are living in an age when achievements of major character and importance are occurring with such rapidity that the spectacular is becoming almost commonplace. The limitations of yesterday are swept aside in the accomplishments of today. So fast is our pace that our very tempo blurs the path we travel, and we find it increasingly difficult to keep our perspective and to take full advantage of present knowledge and experience in working out the problems of the future. We are approaching the dream of a "white civilization," free from smoke with its attendant diseases. The development of fuels alone in the next ten years will carry us to greater heights of prosperity than we have ever enjoyed before. How shall we rank then as a World Power? In this age of mechanical energy, our nation, which leads the world today, need not take second place to any other.

The By-Products of Safety

By JOHN A. OARTEL*

In recent years American industry has been much concerned in the elimination of waste and the utilization of by-products wherever possible. In some instances the by-product has become more valuable than the main commodity, and has added to the wealth and well-being of the country.

*Chief of Safety Bureau, Carnegie Steel Company, Pittsburgh, Pa.

Organized safety in American industry had its inception in 1906, and, during its 22 years of existence, has not only made remarkable developments along the lines originally planned, but has also brought with it some by-products that have vastly improved our industrial life. A few of these by-products are as follows:

First. Safety has been an aid to production.

I have recently read the report of a survey of

the American Engineering Council. The extent of the data obtained and analyzed represents the experience of 14,000 industries employing 2,500,000 workers. The persons who made the survey were not safety enthusiasts, but trained engineers who did not accept data on mere faith but submitted everything to a critical analysis. Had their findings been unfavorable, they would not have hesitated to submit a report to that effect. A comparison of the rates of 1922 and 1925 for a large representative portion of American industry shows: 12 per cent increase in production with an 18 per cent decrease in accidents. To be more definite and to bring out a few specific incidents that have come under my own observation I want to use an illustration, the

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Blast Furnace, which is the first step by which the iron ore from our hills is finally transformed into iron and steel for our railroads, our autos, our bridges and our homes. Without the Blast Furnace the age of steel in which we live would be impossible. The average Blast Furnace has shown a 60 per cent increase in production during the last 10 years, with 50 per cent reduction in accidents. A recent record of a Blast Furnace plant in the Pittsburgh District is worthy of mention. This plant made a record of 238 days without a lost time accident. The average force during this time was approximately 850 men, the hours worked being 1,772,680. They produced during that period 1,066,110 tons and handled 94,548 cars, of which 36,008 were ladles of molten iron and 26,190 ladles of molten slag.

Rolling Mills are also typical of American industry. I have the record of two Rolling Mills of the Pittsburgh District. I quote two letters from the Superintendent of these mills to his employes:

April 1st, 1927.

"TO ALL THE WORKMEN:

"Yesterday ended the first quarter of the year 1927.

"You have gone through January, February and March without a single lost time accident.

"I want to congratulate all of you on this excellent showing and hope every man in your two mills will read this simple little notice and think what this really means to you and your families.

"I also want to congratulate you on the quality of the product you have turned out.

"While the tonnage has been greater in previous years, the quality of the product you have shipped in the past three months has brought less complaints from our customers.

"Let us try to duplicate this good work during the next quarter.

"Sincerely,
(Signed) "John Smith,
"Superintendent."

April 1st, 1927.

"NOTICE"

"TO ALL WORKMEN:

"In January your mill rolled 20,812 tons of steel and not a lost time accident. At that time I mentioned that it was a wonderful record for starting the new year.

"Yesterday you finished up the first quarter of the year with another monthly record of 21,934 tons for the month of March, or a gain of 1,122 tons over your previous best record.

"You have also finished up the quarter with a record for no accidents. Congratulations are again coming to all who performed this good work.

"Records in rolling tonnage are made possible particularly by the class of orders the mill is handling. Records in 'Safety' are made possible only by constant carefulness of every man. Your record in 'Safety', indeed, shows it.

"Sincerely,
(Signed) "John Smith,
"Superintendent."

Many more illustrations could be cited but this will suffice to prove that Safety increases production.

Second. Safety also promotes a better feeling between the employer and the employe, which is a very essential factor if American industry shall continue to prosper and lead the world. No organization can be successful in which co-operation is lacking.

I was greatly impressed with a late magazine article descriptive of Herbert Hoover. In it, the author tried to account for Hoover's efficiency and popularity. He described the great accomplishment of food relief in Belgium, the Near East, and in connection with the Mississippi flood. This author had had a first hand opportunity to study Hoover and observe him in these undertakings. He stated that the result of his observations shows conclusively that Hoover was successful because he secured a large measure of co-operation. His paid helpers were few in number, but in addition to them, were men and women from every walk of life who assisted him without pay and who were eager to help him put his program across.

Now, I have wondered how Hoover could go into strange countries and secure such co-operation, and I have come to this conclusion, which I believe is a correct one, the work which he was doing was for the benefit of the people at large; it was designed to nourish their bodies and preserve their lives until such time as they could become self-supporting again; it was an undertaking every one believed in, so that it was not necessary to sell them the proposition.

In Safety, we have common ground for employer

and employe, and with both standing together on that common ground, it is not difficult to take up other problems and solve them satisfactorily. I have been in hundreds of safety meetings in manufacturing establishments and have seen superintendents, foremen and workmen sitting around a table discussing a job on which there was no argument—"Safety." Then the group would separate and go to their respective positions—the superintendent to his desk, the foremen to assume the directing of the process, and the workmen to their jobs; and that fine spirit of good-fellowship, harmony and co-operation, engendered in the safety meeting, would still prevail. If production was to be speeded up, every man did his bit; and if other difficulties were to be ironed out or adjusted, it would be done in the same spirit.

Yes, Safety is a common meeting ground—a neutral zone over which floats the white flag of peace and where other flags are unknown. This being so, the wise employer, superintendent or foreman who will give safety his honest and sincere support, will find that it will pay handsome dividends.

Third. In addition to the good things previously mentioned, Safety broadens the individual, both employer and employe. If we could examine the reason for all the wars that have cursed this old world, we would find invariably that an individual or a group of people wanted more than his share of this world's goods, or more property than rightly belonged to him. These selfish individuals, in order to realize their false ambitions, have left a trail of war, bloodshed, poverty and disease down through the ages. On the other hand, when we consider the men who have blessed the world, we find that they have been actuated by unselfish motives. They have considered the other fellow. The result of their unselfish consideration has been the designing of process to make men's work easier, the search for remedies to cure and banish disease, and the building of a social structure that would make life happier and living more worth while.

Safety is not a matter for individual practice. We must, in order to bring it to its fullest fruition, think of others. The manager of a plant who plans safety for his establishment, will necessarily think of his employes individually and collectively. They will pass in mental review before him and he will be led to consider their individual peculiarities. He will find that in order to put across a successful safety program, certain adjustments will have to be made and some of them will have to be made in his own character and make-up. He will find that he will need to practice some high-class salesmanship in order to sell safety to his organization. Now, as you know, the salesman caters to his prospect, in fact, he becomes "all things to all men" in order that he may win them to the proper consideration of the articles he sells. What does the successful selling of safety result in? The inevitable result is that the manager becomes a bigger, a better, and a broader man.

Along the same line, the workman who supports safety is careful, not only about his own actions, but in addition does his work in a manner that will keep his fellow workmen free from accidents.

And so, in Safety, we have a mighty principle at work, nay, it is a divine principle that is slowly and surely transforming this country into a workmen's paradise. Our captains of industry conduct their business, not for gain alone—they are becoming more and more interested in the prosperity, happiness and safety of their employes. The men who man our great industries, our mines, our railroads and our public utilities are not mere cogs in the wheel. With an over-growing interest in the safety of themselves and their fellowmen, they do their work cheerfully and well. Their horizon is broadened and their outlook on life is entirely changed.

Since I have been connected with the iron and steel industry, many changes have taken place. There have been mechanical improvements; electricity has become an important part of it, and chemical processes have added their quota to its advancement.

One day in June, 1927, I stood in the great motor room of the new structural mills of the Homestead Works of the Carnegie Steel Company. I was one of a thousand men crowded into that room who were expectantly waiting for the motors to start. At the same time, the late Judge Gary sat at his desk in New York City, 500 miles distant, and at the appointed time, the Judge passed his hand over a glass globe and started the current of electricity which was amplified many times, and carried by wireless to the great motors at Homestead, and the expectant crowd saw the motors begin to turn, set in motion by the wave of a human hand. I do not expect to see a greater marvel of science in my lifetime but I have seen a greater marvel than that come into our steel mills and manufacturing establishments. I have seen "Safety" come in and by its beneficent influence transform our industries into clean, pleasant and safe working places where the chief emphasis is placed, not on production, but on the conservation of human life.

The Evolution of Electrification in the Manufacturing Industry

By F. H. KITTREDGE*

How many of the average persons who are now interested in the Electrical developments of the present era, will take or has taken time to look back over the past forty-seven years to that period; when the adoption of Electricity for General Commercial purposes (except for lighting) was actually accepted and made possible.

It is worth one's while to range over the past

* Electrical Engineer, Illinois Steel Co., Joliet, Ill.

and present status of the Evolution in our Electrical field for comparison if nothing else.

The progressive demands for more flexible power drives and other necessary apparatus such as general purpose utensils and labor saving devices has greatly brought out the possibilities of the use for Electric power in a vast number of applied methods. There seems to be no limit as to the application of Electric power.

Many years ago we accepted the class of apparatus designed at that time with the full knowledge that it was the best that the Electrical designing engineers had to offer with his limited knowledge as to just what was required for the specific or individual case or installation. He worked along the lines of developing an ethical rotating mechanism with as much efficiency as he was able to obtain and actuated by Electric current of either A. C. or D. C. quality.

F. H. KITTREDGE

He figured that if the motor and control would furnish the rated Horse Power at a reasonable efficiency: the results were satisfactory, but not so.

The progressing field demanded more than the old manually operated controller as an ultimation of control and the so called all purpose motor, which in fact was only built and designed to operate in a clean locality; without the true knowledge of the severity or continuity of service in specific locations.

Many a battle royal was fought between the mill engineer and his superiors and the factory designing engineers as to reason of continual failures of the old apparatus. The mill engineer had to take the knock between the two and the little alibi travelled fast; but after years of personal experience with all phases of electrical installation and conditions he decided conclusively that electrical apparatus must be tailored "So to speak for efficient factory and mill installations. This refers not only to motors but transformers and control.

The rugged mill type motors and the automatic controls of today are the results of the united work and demand of our mill engineering organization in conjunction and co-operation of the electrical designing engineers.

Years ago, I can remember the old time reversing controller for a series motor control, using a series of mercury cups into which copper wires would make immersion contact in sequence as the arm was thrown from one side to the other as required for reversal, etc., and the old Gram ring wound armatures that needed one or two coils changed most every turn in the day, no dynamic braking, just solenoid brakes with mechanical types in conjunction.

Then came the design and application of lifting magnets, Electric fans for mill service, Electric heating units with a vast increasing application and demand. Lighting systems in which the old high voltage series Arc lamps fast became the thing of the past and incandescent units were developed to operate across standard low voltages. All of these cycle changes progressed very rapidly, until we now have efficient types of systems suitable for any location, either in the Rolling mill or in general service purposes.

One could go on and rehearse thousands of applications and apparatus which has been developed since the year 1889, but we have not the time or space to dwell further on this rapidly increasing cycle.

If the boys of today think they have troubles (Even with the mass of Electrification) they are badly mistaken.

The future of Electricity is far reaching in possibilities, no one knows how far research will carry us, while a mysterious energy or force we know little of its exact origin and what relativity it has to the composition of life and matter. The molecule, atom and ion all have future possibilities. Just what, we know not, but research may at some time hence tell the world just what Electricity is.

The fact of its mysterious complexity has caused a continued desire for search which in turn has brought forth new possibilities of design and control to suit the much demanded conditions and requirements of the market.

The tonnage and outputs of all classes of Manufacturing Plants has greatly been increased by the adoption of electric motor drives, with their automatic controls for faster speeds and flexible operation.

The financial status in relation to a better design of apparatus with higher speeds and continuous service is a direct result and is self evident.

In summing up the subject from the early periods up to the present time the evolution of electrical equipment has been phenomenal. There is a special design (so to speak) for every demand and in some cases many of these designs which used to be special are now standards for the location and drive.

With the new generating equipment, such as Gas Engines, Steam Turbo and Diesel driven generators with the large mill installations and auxiliaries, the field today is well covered with apparatus for any specific condition on demand.

The mechanical design of all Electrical apparatus is as important as the Electrical end, consequently the result is; that we have sturdy and rugged constructed motors and control with anti-friction bearings and other mechanical features which make a combined efficient apparatus to meet any emergency.

And we still look forward to future developments which will revolutionize the present Electrical field.

Electric Heat

By ROGER H. BRYANT*

Electricity is every day becoming more and more the universal medium for the transmission of energy. There are many reasons, chief among which are the efficiency, ease of control and the readiness with which it may be converted into other forms of energy and made to do work, provide heat and light and produce chemical reactions. Steam engines or other prime movers are seldom mechanically connected to the machinery that they will ultimately drive because the interpolation of electricity permits each piece of machinery to be driven at correct and easily changed speed, started and stopped at will, placed where most convenient, and moved or changed readily without troubling other machinery and without cumbersome parts which are expensive, require considerable maintenance and which in themselves absorb appreciable energy. Artificial light is an absolute necessity of modern life both in industry and at home and electricity provides by far the best, safest, most economical and easiest method of obtaining it. Our supply of many metals and other substances is due directly to the chemical reactions produced by electricity and undoubtedly, many advances are yet to be made in this field. But the application of electricity to heating problems does not seem to be advancing as rapidly as it might and there apparently is a great opportunity to use it to advantage in the iron and steel industry where the working of these materials is one heat treatment after another.

The chief reason that electric heat has not advanced more rapidly has been an economic one. This is especially true in those regions where the cost of electricity is comparatively high, due to lack of abundant water power or sources of cheap fuel or by-products from which electricity can be generated. If the heating operation consists essentially of supplying nothing but heat enough to raise the temperature of the material to at least a given point, then the comparison of heating costs approaches a simple heat unit basis, with of course due allowance for difference in efficiency of furnace, repairs and maintenance, etc. on which basis it is exceedingly hard for electricity to compete with either gas or oil unless the fuel fired furnace is very poorly designed. But is the economic side of the question the only one to be considered? Are not the improvements in quality obtainable by accurate control, the decrease of rejections due to a uniform treatment ,the saving in space due to elimination of fuel storage, auxiliary equipment and products of combustion, the improvement of working conditions and the reduction of the fire hazard worth serious consideration?

There is no question but what electric heat is the easiest to control accurately although good results can be obtained with gas as a fuel. It is standard practice to provide electrically heated equipment with control apparatus to maintain a given temperature within five degrees over or under and if there is necessity for doing so, as in some laboratory apparatus, this deviation from prescribed temperature can be kept to a small fraction of a degree. It is well known that changes produced in steel by heat are a function of time and temperature and while many changes can be produced over a wide range of temperature, good practice calls for accurate maintenance of a specific temperature so that uniform results can be obtained.

There is another point in connection with quality which has not received very much consideration to date and that is, that steel, especially in elongated form such as wire or bars, can be heated very quickly by the direct passage of electricity through it. Thus heat is generated in all parts at the same time and the rate of generation depends on the rate at which electric energy is supplied. By this method, it is possible to heat steel as rapidly as desired even to the point of vaporizing it with explosive violence. The possibility of quick heating offers many advantages, especially for use with carbon steels of particular analysis which when subjected to the atmosphere of fuel fired furnaces suffer change in composition especially on the exposed surfaces. Then too, steel left in a furnace long enough to reach rolling temperature invariably becomes coated with scale which must be removed before rolling.

Electric furnaces in general occupy more space than fuel fired furnaces but this direct comparison does not take into account the space required for the storage of oil and the pumps for conveying it to the furnace, nor the compressors for gas and air, nor the space occupied by flues and chimneys to carry away the products of combustion. If all factors are taken into account, the electric furnace will show a saving in space in spite of its thicker heat insulation. Then too, it may be placed anywhere in the line of production without thought of flues, etc., because its heat energy is supplied over wires which can be easily run to any point.

Much attention has been paid during the last ten years or so to the prevention of accidents, both to men and machinery. Electricity as a heating medium offers a decided advantage in the reduction of the fire hazard. Many heat treatments require the quenching of red hot steel in oil which is at best a fire hazard without having a roaring furnace spouting flame only a few feet away. Also, electric furnaces are capable of being better insulated against heat losses so that working conditions around them are greatly improved.

All these advantages of electric heat are well known to electrical engineers and to others who have had experience with them, but are they as well known and are they given all the consideration that is due them by superintendents and other executives when new heating installations are being considered? That is where the electrical engineer has a duty to perform. It is directly up to him to keep in touch with all new heating installations, make a careful analysis of the work to be done, estimate as accurately as possible the comparative cost and the advantages and see that all factors receive the proper consideration.

* Electrical Engineer, American Steel & Wire Company, Worcester, Mass.

Installation Costs

By G. W. BAUMGARTEN*

"Competition is fierce" is a familiar expression and can be heard many times when conversing with salesmen handling the retail sales of such commodities as radios, electric refrigerators and automobiles.

Competition is just as keen in the steel industry and although the layman doesn't hear it as often, the executives in a steel plant have it forced upon their attention daily. Such statements as "Our cost per ton of pig iron is higher than 'Plant B', how can we reduce it?" "Our cost per finished ton of steel and our labor costs are higher than 'District X', we must reduce them or our orders will be shifted to other plants," are quite familiar to departmental superintendents.

The cost of any finished product is composed of the cost of the raw material, the cost of handling, cost of manufacture, plant overhead, selling cost and a fair profit.

A departmental head at a manufacturing plant can affect only three of these items. They are, the cost of handling the raw material, the cost of the various manufacturing processes, and the overhead.

Raw and semi-finished material is handled by electric cars, steam locomotives and electric cranes. Manufacturing processes are pretty well standardized but in an old plant which contains old boilers, small generators, inadequate cranes and mill operations which are performed by steam engines and hydraulic equipment it is possible to show substantial savings by installing modern equipment and using electric drives on practically all mill operations. These improvements generally will effect a big reduction in manufacturing costs.

"Overhead" is that insulting term which is applied to any costs which are not directly allied to the production of steel. All maintenance, inspection, testing, repairing and engineering which is done under the supervision of the Electrical Superintendent is classed as "overhead" by the men in the production departments. By buying the proper equipment and installing it with due regard to conditions under which it must operate and the men who must maintain it, this "overhead" cost can also be controlled to a certain extent.

In an effort to reduce these costs it is only natural that the cost of "proper equipment properly installed" will be considerably higher than the standard of fifteen or twenty years ago. An installation which formerly consisted of weatherproof wire on insulators, a fuse box, a Dinkey controller and a railway type motor, now requires rubber covered wire in conduit overhead, rubber covered lead covered cable in conduit encased in concrete underground, a magnetic controller providing complete protection, adequate resistors of proper capacity and mill motors equipped with anti-friction bearings.

The same comparison holds true when installing new cranes. The $10,000 crane of 1910 costs $30,000 in 1930 and is equipped with worm gear reductions, one-piece cast steel trolleys, heat treated track wheels, safety walks, magnetic control, conduit encased wiring and anti-friction bearings.

Naturally mill officials are aghast when estimates are presented which involve such large expenditures, and the electrical superintendent is besieged with questionnaires as to the necessity for this equipment, the estimated savings as compared to other equipment and the percent return on the investment. These questions must be answered by pointing out that the electrical equipment in the mill is steadily increasing in size, numbers and complexity, that the same (or smaller) maintenance force of ten years ago must inspect, maintain and repair this equipment, that labor rates for these maintenance men have no attraction for the high grade man who is really needed, that the week-end repair turn is generally limited to eight hours while the repair gang must be kept as small as possible, therefore all installations must be made as nearly "trouble proof" as possible and the proposed installation is the preferred method of reducing handling, manufacturing or overhead costs.

The above facts are substantiated by the following conditions which occurred in a given plant. During a recent seven year period the number of motors and the total installed horsepower increased 48% while the maintenance force decreased 17% and the shop forces decreased 16%. This is equivalent to a total reduction of 43% in the maintenance forces per motor installation. Yet during that same period mill delays were reduced 61%. Considering the increased number of motors, this is equivalent to a 74% decrease in hours delay per motor.

Such facts when properly presented usually justify what is apparently a very expensive installation. A good deal of missionary work along this line, no doubt, remains to be done, so that the Electrical Superintendent may devote his time to planning and installing improvements rather than justifying their estimated cost to his superiors.

*Assistant Electrical Engineer, Carnegie Steel Company, Duquesne, Pa.

IRON AND STEEL EXPOSITION

The Iron and Steel Exposition is an institution that is fostered, sponsored, owned and controlled by the only engineering organization in the United States whose activities are exclusively devoted to the problems of the Iron and Steel Industry.

The Iron and Steel Exposition is just ONE of the activities of the ASSOCIATION OF IRON AND STEEL ELECTRICAL ENGINEERS. It is, however, one of its valuable functions, and it assists in rounding out the operating cycle of this Society.

During the year this Society conducts technical sessions in all of the leading Steel centers of the United States; discussing the operating and maintenance problems that confronts our vast Industry. All this data is then compiled, edited by the Executives of the Industry and distributed throughout the Steel World through their official medium, the IRON AND STEEL ENGINEER. This periodical, a monthly paper, acts as a clearing house for the problems of this Industry.

Another important function of the Association are the Inspection Trips. Inspection Trips are made to the various Iron and Steel Plants to inspect and examine the most modern and up-to-date equipment and methods in service.

Once a year the Manufacturers who service the Iron and Steel Industry are presented an opportunity to display or exhibit the new developments in their product and equipment to the buyers and operators who are the men who will in the final analysis be responsible for the installation, operation and maintenance of millions of dollars worth of equipment purchased by our Industry, annually.

The attendance at the Iron and Steel Exposition is confined principally to the Iron and Steel Industry and represents a purchasing power which means millions of dollars each year. The attendance is almost hand-picked, it represents executive and engineering talent of the Steel Making Art. The results that are to be obtained in the Iron and Steel Exposition are evidenced by the fact that the largest manufacturers of equipment in the world are with us each year.

It will be readily seen and appreciated that the Iron and Steel Exposition has its place; that it has a true function and co-ordinates with the balance of the activities of an Engineering Society. Manufacturers should keep in mind that the contacts made at the Iron and Steel Exposition may be continually renewed through the many various activities of the A. I. & S. E. E. during the year.

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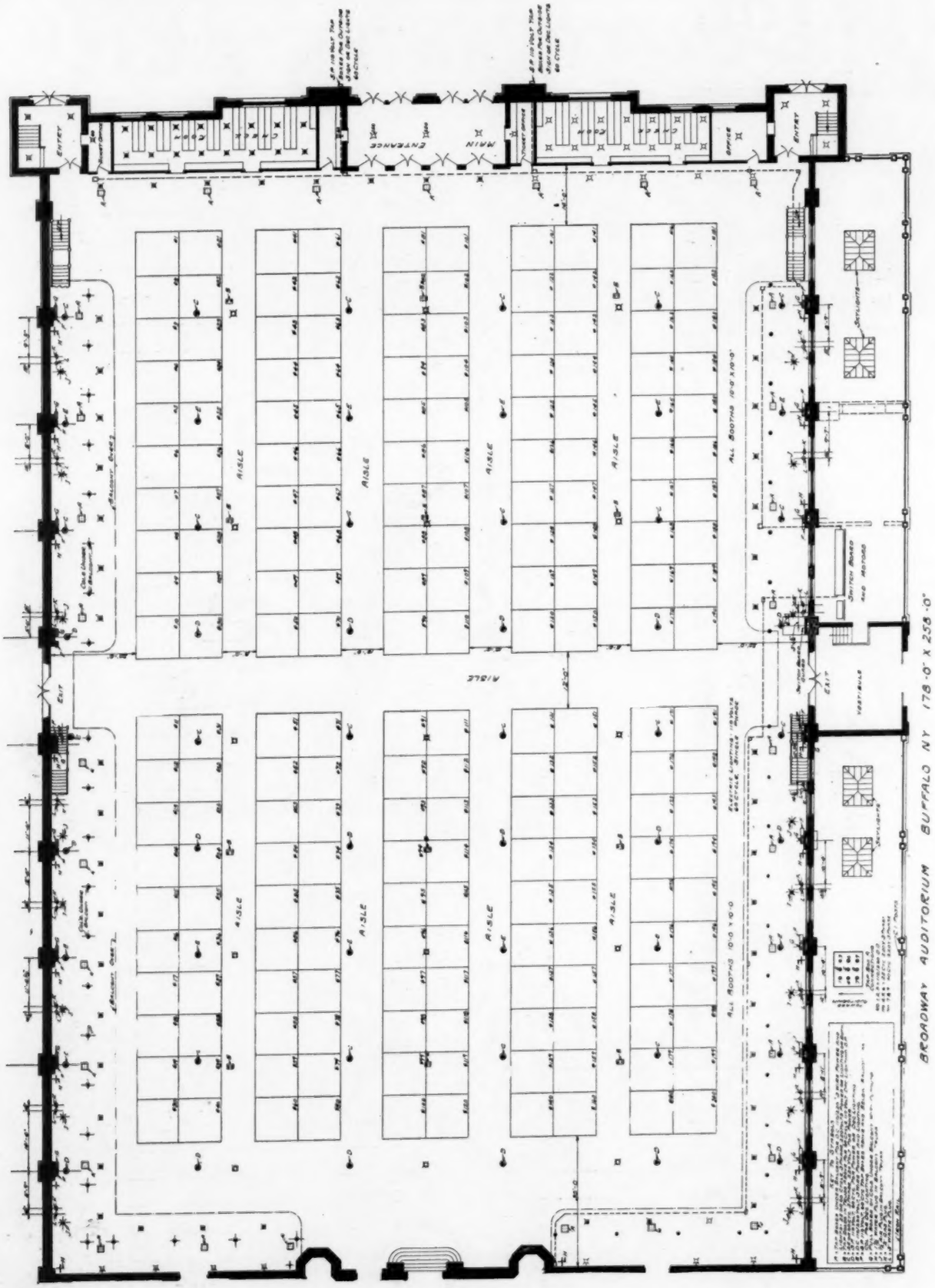


Floor Plan for Iron and Steel Exposition, Buffalo, N . Y., Broadway Auditorium, June 16th to 20th, 1930.

M. J. CONWAY
General Chairman, Tuesday, June 17th
Combustion Engineering Division

J. H. VAN CAMPEN
Chairman Registration Committee

C. L. BAKER
Chairman Safety Engineering Session
Monday, June 16th, 1930

WALTER DeFRIES
Author

MRS. RUTH BRYAN OWEN
Speaker at Reception and Dinner Dance
Thursday, June 19th

J. B. AUSTIN
Author

W. E. MILLER
General Chairman, Monday, June 16th
Electrical Engineering Session

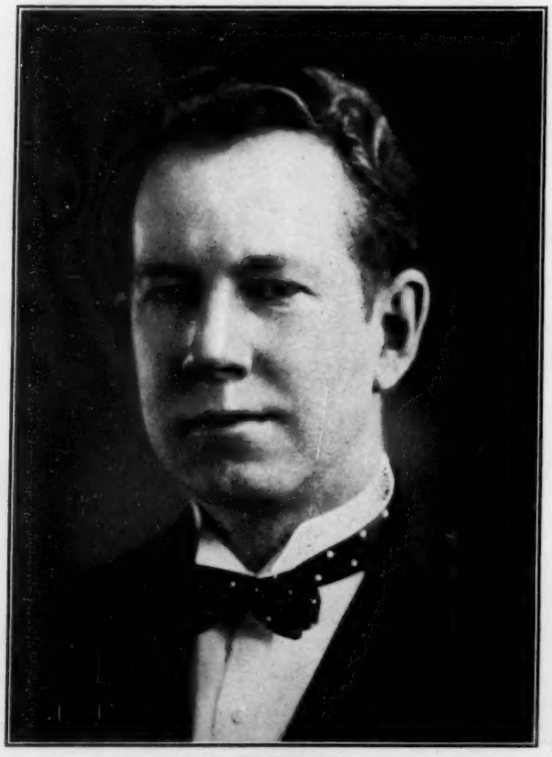
GORDON FOX
Speaker at Luncheon, Monday, June 16th

F. E. LEAHY
Chairman, Tuesday, June 17th
Combustion Engineering Session

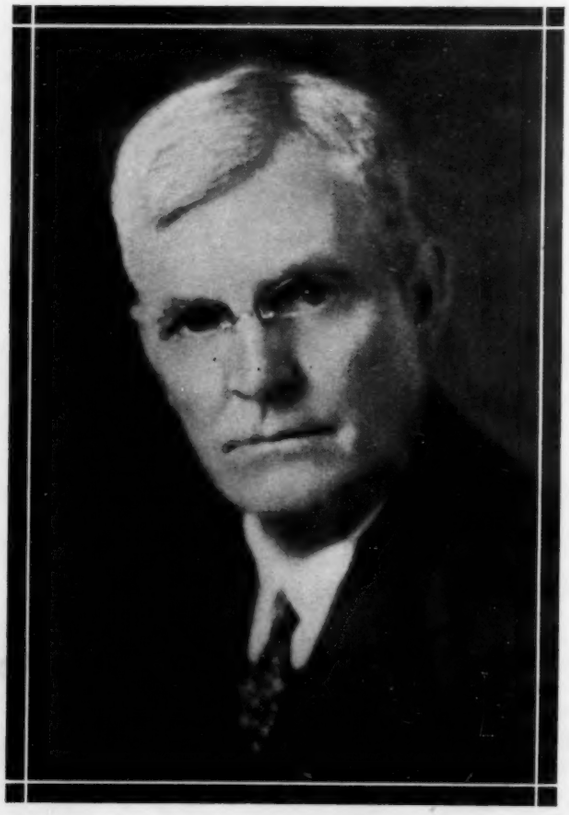
J. J. BOOTH
Chairman, Shop Practices Committee

W. S. HALL
Chairman, Iron and Steel Exposition Committee

S. S. WALES
Chairman, Electrical Engineering Session, Tuesday, June 17th



R. S. SHOEMAKER
Chairman, Electrical and Combustion Engineering Session, Tuesday, June 17th



C. S. PROUDFOOT
Chairman, Informal Reception, Monday Evening, June 16th

The Electrical Development at the Lackawanna Plant of the Bethlehem Steel Company*

F. D. Egan†
J. F. Oehler‡

The Association of Iron and Steel Electrical Engineers' Convention, meeting in Buffalo and having as one of its features an inspection trip to the Lackawanna Plant of the Bethlehem Steel Company on Friday afternoon, June 20th, has prompted the preparation of this paper covering the development of the Plant from an electrical standpoint in order to serve as a guide to those who may participate in the inspection trip. This paper is written to give a general description of the equipment and method of operation, rather than to stress any one particular division of electrical development.

The Lackawanna Plant is located at Lackawanna, N. Y., and extends 3 miles southwest from the city limits of Buffalo on a strip of land bordering on Lake Erie and having an average width of 3000 ft. Fig. 1 above, shows a general view of the entire plant.

The plant is now equipped to manufacture the following materials: Pig Iron, ingots, billets, blooms, slabs, sheet bars, heavy and light rails, tie plates, splice bar, structural shapes, sheared and universal plates, merchant bars, reinforcing bars, sheet piling and fabricated structural material. The iron and steel production equipment consists of 7 Blast Furnaces and 2 Open Hearth Plants, including 2 Tilting and 22 Stationary furnaces.

The ore and limestone is brought by boat to the canal extending into the grounds of the plant. The canal is 4000′ long, 200′ wide and 23′ deep. The dock has five 10 ton Hulett Unloaders with skip conveyors and two 17 ton Hulett Unloaders with belt conveyors. The unloaders handle annually, approximately

* To be presented at AI&SEE Convention, June 16-20, 1930.
† Elec. Supt., Bethlehem Steel Company, Lackawanna, N. Y.
‡ Elec. Engr. Dept., Bethlehem Steel Company, Lackawanna, N. Y.

2,380,000 gross tons of ore, 600,000 tons of limestone and 600,000 tons of coal. On the side of the canal opposite the Unloaders, there is 2400′ berthing capacity which is equipped with two 5 ton special twin loading derricks and two 10 ton portal type revolving cranes used for the loading of the manufactured products for shipment up the lakes to Chicago and Duluth and for the unloading of scrap material sent down the lakes.

The coal and coke oven sections are made up of a coal storage and handling space of 450,000 tons equipped with a 300′ span, 2400′ traveling bridge and a system of belts which deliver the coal to and from the coal storage and from the car dumper directly to the ovens. There are four batteries of Coke Ovens, one Semet Solvay and three Koppers' type, with a total of 231 ovens. The annual capacity of the ovens is approximately 1,200,000 gross tons. The products of the Coke Ovens are benzol, naptholine, tar, toluol, light oil and ammonium sulphate. Fifty percent of the Coke Oven gas is used as fuel in the mills, soaking pits and Open Hearth furnaces.

The Plant also contains numerous shops such as Roll-turning, Foundry, Pattern, Carpenter, Forge, Mechanical, Electrical, Structural and Locomotive repair shops; and many rolling mills, either steam or electrically driven. The steam driven mills are the 32″ Slabbing Mill, the 18″ Billet Mill, 24″ Bar and Shape Mill and the 10″ Bar Mill, and the electrically driven mills are the 40″, 44″, 54″ Blooming Mills, 36″ Roughing and 32″ Rail and Billet Finishing mills following the 44″ Bloomer, the 48″ Roughing and Finishing structural mill following the 54″ Bloomer, the 48″ Plate mill, the 35″-28″ and the 18″-14″ structural mills, the 12″ and the 8″ Bar mills.

In order to give some preliminary conception of the kind and extent of electrical equipment in operation in the Plant, the following tabulated information has been prepared.

Power Stations

Turbines	2
Transformer Banks	2

Substations

Total Number	8
Automatic	1
Semi-Automatic	4
Manual	3
Attendant	2
Non-Attendant	6
Mill Drive Motor Rooms	9
Manual	9
Attendant	9
Substations inc.	6
Pumping Stations	4
Terminal Houses	3

Turbines

Number	Capacity KVA	Voltage
2	25,000	6600

Transformers

	No. Banks	No. Transf.	Cap. KVA
Total	24	75	58550
60000/6600	2	6	30000
60000/2200	1	6	6000
6600/2200	1	3	3000
6600/440	10	30	11150
2200/440	4	12	3750
6600/220	6	18	4650

Tansformers Contemplated

	No. Banks	No. Transf.	Cap. KVA
Total	3	9	19000
60000/6600	1	3	15000
6600/440	1	3	3000
6600/220	1	3	1000

Motor Generator Sets—250 Volts D.C.

	Total No. of Sets	Total Capacity of Synchronous Motors
Total	16	23100
Total 6600 volt Sets	14	21000
1400 KVA Sets	10)	14000
2800 KVA Sets	2)=14	5600
700 KVA Sets	2)	1400
Total 2200 Volt Sets	3	2100
700 KVA Sets	3	2100

Transmission Lines

	Number of Lines	Length in Miles
Grand Total	58	19.8
Total 6600 Volt	40	14.7
6600 Volt Overhead	32	11.7
6600 Volt Underground	8	3.0
Total 2200 Volt	18	5.1
2200 Volt Overhead	2	1.7
2200 Volt Underground	16	3.4

All overhead and underground 6600 volt and all overhead 2200 volt lines are 500,000 CM Cables while the 2200 volt underground lines are size 4/0. The spacing on the overhead 6600 volt lines varies from 30″ to 36″ and the 6600 volt underground is standard 3 conductor, 15,000 volt, varnished cambric insulation, lead covered.

Oil Switches—Transmission Lines

Total	94
60,000 Volt	4
6600 Volt	67
2200 Volt	23

Oil Switches—Station

Total	114
6600	78
2200	36
Grand Total	208

Motors	No.	HP or KW
Mill Drive Motors		
D.C. Reversing	12	64,500
D.C. Continuous	3	4,500
A.C. Continuous	5	5,550
Total A.C. and D.C.	20	74,550
Flywheel Sets		
A.C. Induction Motors	8	43,250
D.C. Generators	21	57,300
Slip Regulators	8	
Regulating Sets		
A.C. Motors	5	1,325
Induction Generator	5	1,240
Mill Drive Motors and Generators		
Total HP—D.C. and A.C.	33	119,125
Total KW—D.C. and A.C.	26	58,540
Mill Motors		
A.C. Mill Motors	953	34,057
D.C. Mill Motors	1,530	64,398
D.C. Crane Motors	965	44,992
Total D.C., A.C. & Cranes	3,448	143,447

Grand Total	3,481	262,572
Cranes Total	244	
Cranes (Contemplated)	20	
Gantries	10	
6600 Volt Machines Being Installed		
Mill Drives		
A.C. M.G. Sets	3	9,940
A.C. Continuous	3	9,000
A.C. Fans and Pumps	3	1,900
Mill Motors—Low Voltage		
A.C. Mill Motors	68	5,711
D.C. Mill Motors	140	4,856
D.C. Crane Motors	98	8,165
Total	355	39,572

Power System—No. 3 Power Station

No. 3 Power Station, which is the main source of power for the plant, is located in the south end of the yard and consists of Railway Industrial galvanized bolted steel structure in the foreground and a brick building in the background as seen in figure 2.

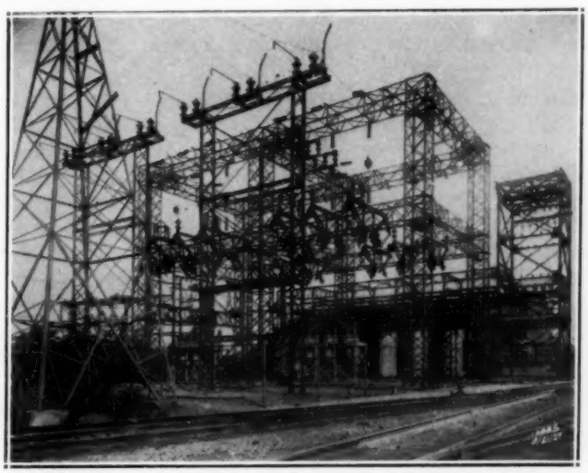


FIG. 2.

This station is fed from the Gardenville substation of the Niagara Falls hydroelectric stations by two 60,000 volt, 25 cycles, 3 phase overhead lines. In this station are located two banks of 3 single phase outdoor transformers rated 15,000 KVA, 60000/6600 volts, water cooled, delta connected and a bank of six 1000 KVA, 60000/2200 transformers, water cooled delta connected with two transformers in series on each side of the delta on high tension side and two transformers in parallel in delta on low side. These transformers are then paralleled with the steam turbine station at the other end of the plant by means of six 6600 volt, 3 phase circuits and two 2200 volt, 3 phase circuits through a 2200/6600 volt swing bank of transformers at No. 1 Power Station.

Eighty percent of the power used in the plant is distributed from this station and is purchased from the Power Company. A block load of power is maintained at this station at a high load factor. The average load at the present time is 19,900 KW and the maximum 15 minute demands have averaged 21,330 KW and the highest demand was 22,692 KW. The load factor based on the 15 minute demand is maintained at 89% throughout the year, offering a very desirable load for the Power Company.

The block is maintained by means of an automatic peaktaking system consisting of contact wattmeters which operate on the instantaneous loads. The load on reaching a predetermined value regulated by the setting of the contact wattmeter actuate relays operating torque motors on the Slip Regulators of the Induction motor flywheel sets in the mills for a certain predetermined length of time and then energize solenoids operating on the governors of the steam turbines at No. 2 Power Station for sustained loads.

The incoming lines, No. 1 and No. 2, Lackawanna Trunks enter the south end of the structure over steel towers, one of which is shown on the extreme left of figure No. 2. From the last towers of the Power Company, the 60,000 volt lines pass over the top of the H tower on which are mounted the lightning arrester's equipments. This consists of horn gap lightning arrester, S.P.S.T. Disconnect switch and resistance tube. The lines are deadened at the top of the 60,000 volt structure. Inserted in the vertical bus are choke coils for protection on the incoming lines. The outside phases of each 3 phase line runs from the choke coil to the ring type Nicholson current transformers and then with the middle phase, are taken to the main incoming gang operated disconnect switches. The current transformers are used by the Power Company for their meters.

The lines are brought down from the bottom of the gang operated disconnect switches to the oil switches D-39 and D-40 which are the main incoming line oil switches and are shown in figure 3. The oil switch throw, electrically operated with 250 volt D.C. control. The breaker is rated at 20000 amperes for 5 seconds and has an interrupting capacity of 9700 amperes at 60000 volts. There are six bushing type current transformers with a ratio of 300/5 amperes in each switch. Three of them are on the line side of the switch and are used for the relays, while those on the north side of the switch are used for the meter and peaktaking systems.

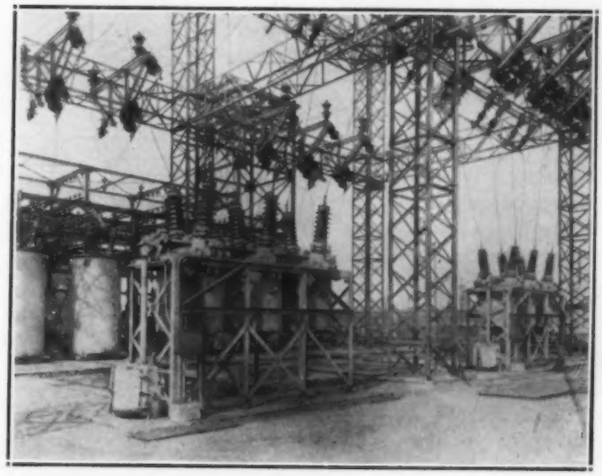


FIG. 3.

From the oil switch, the lines go to another set of gang operated disconnect switches similar to those on the line side of the switch and mounted on the opposite side of the structure from the disconnect switches mentioned above. From the top of the disconnect

switches, the lines are taken upward and tapped on the 60,000 volt bus which extends across the top of the structure as seen in figure 2. The bus is divided into two sections with each of the incoming lines feeding a section. The two sections, however, are normally tied together, through a gang operated disconnect switch which is mounted on the top of the center cross piece of the structure.

At the west end of the 60,000 volt bus, taps are taken off and led down the west side of the structure to two Westinghouse 5 K.W., 25 cycle, 60,000 to 220/110 volt potential transformers used by the Power Company for meters on the 60,000 volt system. The potential circuit is protected with Schweitzer and Conrad fuses and resistance tubes. Just ahead of the transformer disconnect switches on each section of the 60,000 volt bus, two 60,000 volt lines are run over the top of the steel structure to transformers in the substation.

The two main lines are brought down to disconnect switches mounted on the rear of the 60,000 volt bus structure and they are similar in construction and operation to the switches described on either side of the main oil switches. From the bottom of these disconnect switches, the lines are run to the high tension side of the two banks of transformers.

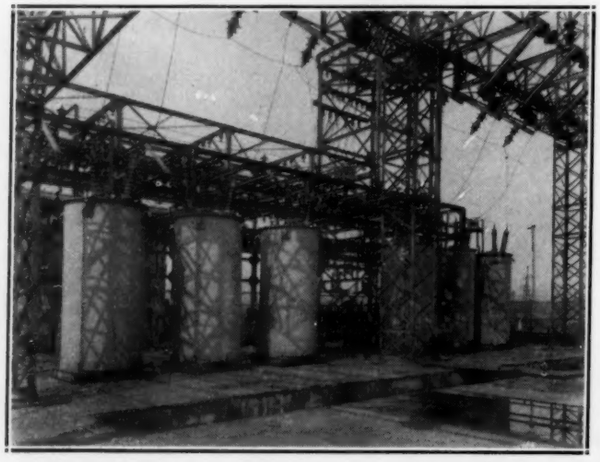


FIG. 4.

Figure 4 shows both banks of transformers. They are mounted on truck bases as seen in figure 4 which are on standard gauge tracks and can be moved out to the trough shown in front of the transformers in which there is another truck, and which connects with the plant railway system.

The transformer is equipped with a tap changing device which is mounted under oil inside the transformer and operated by a handwheel located on the outside of the cover. The switch is used only when the transformer is entirely disconnected from the power. At present, the taps are on 5 and 6 on the primary side for a voltage of 54,000 and 6600 volts on the secondary side, giving a transformer ratio of 8.18 to 1. The efficiency at 1/2, 3/4 and full loads is 98.05 and 98.15 and 98.00% respectively. The regulation at 100% and 80% power factor is 1.9% and 6.9% respectively. The west bank of transformers is similar in construction to the east bank as given above, except the efficiency and regulation are slightly higher.

From the secondary side of each transformer, the two lines extend up to the 6600 volt bus built up in the structure in the rear of the transformers as seen in figure 4. The transformer bus is split into three sections, No. 13 bank of transformers feeding the east section and No. 14 bank feeding the west section. The center section is separated from the east and west sections by two sets of disconnect switches which normally remain open.

A tap is taken off the east, west and center sections of the 6600 volt bus which is taken to a set of disconnect switches shown just back of the transformers on the left of figure 4. The oil switches after the disconnect switches D-38, D-41 and D-37, are Westinghouse type 0-221, 2000 amperes, 25000 volts. From the oil switches, the lines are run to another set of disconnect switches similar to those ahead of the oil switches and then to the feeder bus shown in upper section of the 6600 volt bus structure in figure 5. This feeder bus extends the entire width of the structure and is split into two sections by a set of disconnect switches with two feeders on the east or left hand section as seen in figure 5 and four feeders on the west or right hand section. The disconnect switches are normally closed.

From the bus are also tapped lines for potential transformer circuits used for metering and for phasing in the Niagara power with the steam station power over various feeders. These transformers are rated at 6600/110 volts. From the 6600 volt bus, each feeder is taken through a set of bus disconnect switches, a Westinghouse type 0-221, 1200 ampere, 25,000 volt oil circuit breaker and then through another set of disconnect switches. The oil switches and disconnect switches are shown in the lower part of figure 5. The oil switches are all electrically operated through the 250 volt D.C. Control. The switches will interrupt 53,500 amperes at 6600 volts based on the 2 O.C.O. duty cycle.

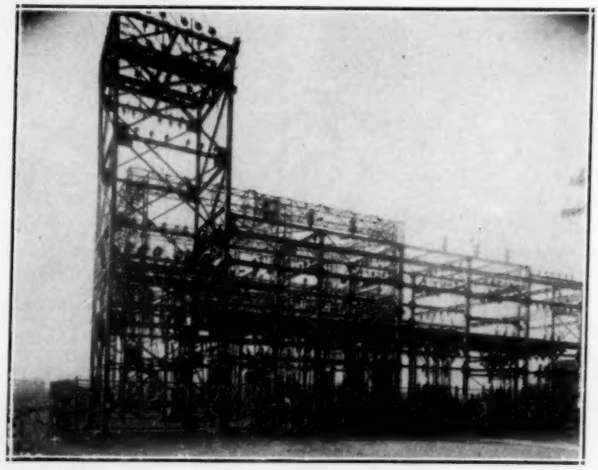


FIG. 5.

Inserted between the oil switch and the disconnect switch of each line, is a set of 3-750/5 bushing type current transformers used for the meters and relays on each feeder. From the disconnect switches, the lines are run to the box tower on the left of figure 4 where are mounted the choke coils which are in series with each line. See figure 6 for wiring diagram of plant.

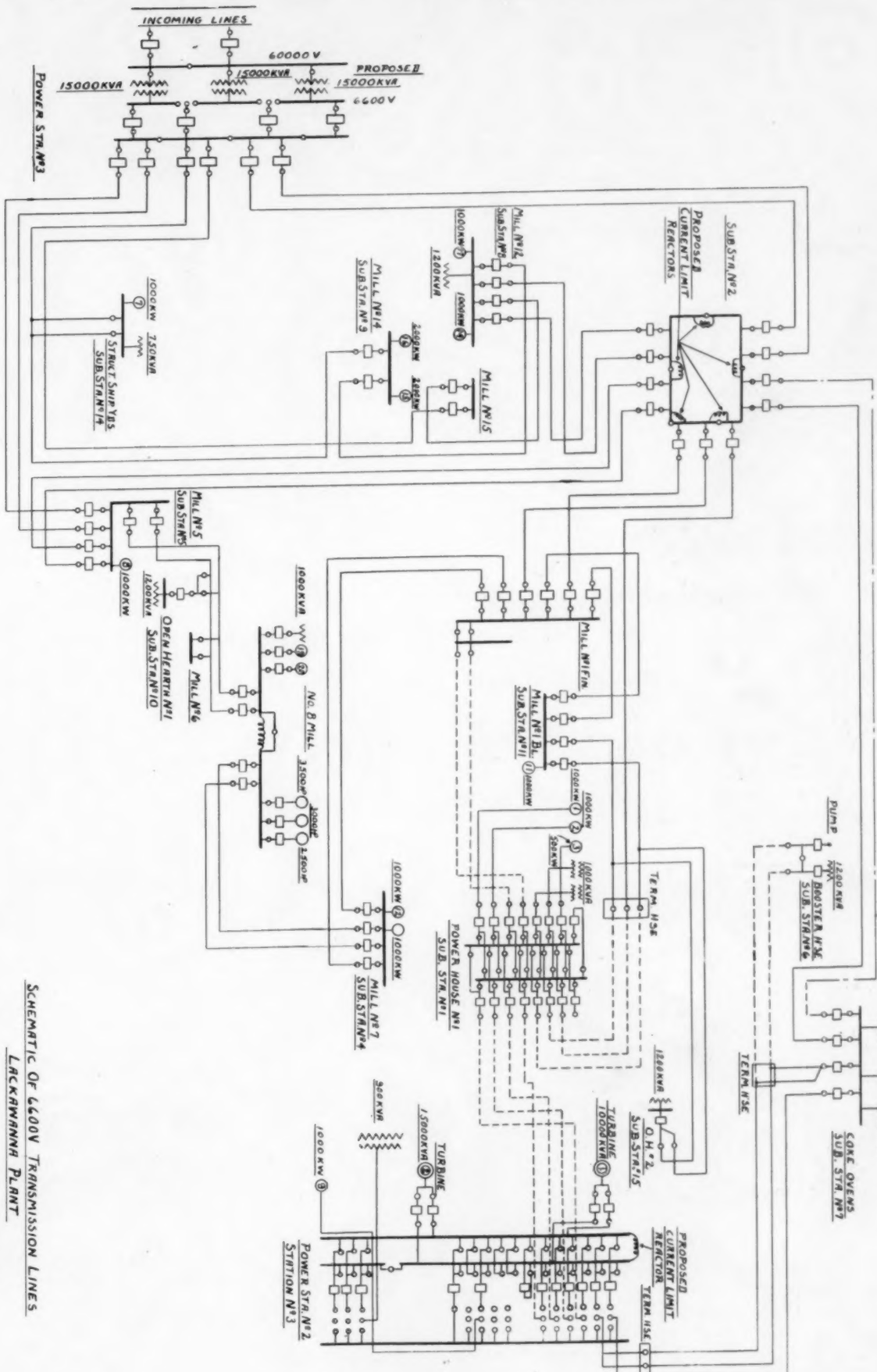


FIG. 6.

SCHEMATIC OF 6600V TRANSMISSION LINES
LACKAWANNA PLANT

LEGEND:- ---------- UNDERGROUND CABLE
—— · —— FUTURE OVERHEAD LINE

Four of the 6600 volt lines and two 2200 volt lines are run to the top of this tower and from there to the various substations forming part of the loop system shown on figure 6. A line is tapped off of each line for the lightning arrester disconnect switches and the type SV lightning arresters. The other two 6600 volt lines are run from the switches at the extreme left of figure 5 to a box tower on the west side of the substation proper and from there to No. 2 Substation which is a part of the loop system.

The 60,000 volt lines extend over the top of the steel structure as seen in Figure 5 and are taken to a set of single pole disconnect switches mounted at the top of the south wall of the substation. The lines enter the building and go to Westinghouse type G, 200 ampere, 60,000 volt oil switches located in the gallery in the substation. Inserted in the circuit is a set of bus type current transformers with a ratio of 160/5 that are used on the meters and relays for the 60,000/2200 volt system. From the oil switch, each line is taken to a 60,000 volt bus through a set of disconnect switches and from the bus, connections are made to the group of six transformers making up what is known as No. 12 Bank of transformers located in a room in the rear of the station.

There are seven Westinghouse 1000 KVA oil immersed water cooled transformers, one of which is used as a spare and by proper switching can be cut into service for any transformer which may be in trouble. The six transformers are rated as 33,900 volts on the primary side and 2500 volts on the secondary side with 3 lower voltage taps on both the primary and secondary sides. At present, the transformers have two primaries in series delta connection and the secondary side in parallel delta connection. The taps are 30,800 volts on primary and 2400 volts on secondary. This bank is thus operated in parallel with the 60,000/6600 volt banks of transformers through a swing bank of transformers 6600/2200 located in the main plant loop system.

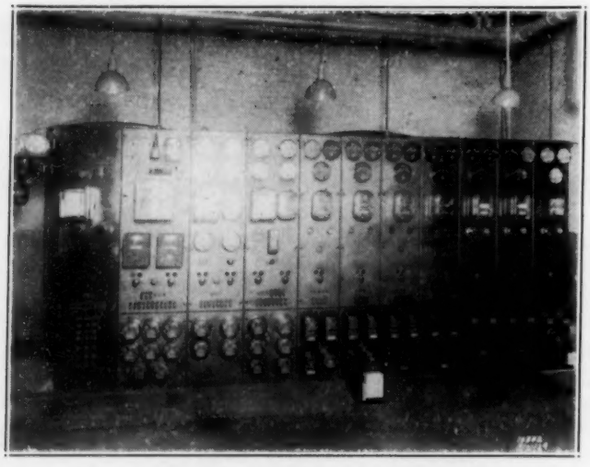


FIG. 7.

From the 2200 volt bus, there are two lines tapped off which extend to a set of disconnect switches to Westinghouse type C, 2000 amperes, 11,000 volt oil switches and to another set of disconnect switches all located on the opposite side of the room from the 6600 volt panels shown in Figure 7. The cable is taken out of the west side of the building to a box tower, and from there, the lines go to the top of the 6600 volt bus structure, previously described, thence to the box tower on the left of Figure 5, and out over the transmission towers to No. 2 Substation. A third switch similar to those above is used to control a set of lighting transformers rated at 2200/440 volts.

Figure 7 shows the Westinghouse control panels for the 60,000 volt and 6600 volt systems. The meters on the extreme left on the swinging bracket are the totalizing wattmeter, the 60,000 and 6600 voltmeters and the synchroscope. The panel on the left contains the Esterline graphic totalizing wattmeter, indicating lamps and the T.P.D.T. switch for the peaktaking system, test links and F.P.D.T. broken back switch for current transformers on the 60,000 volt lines. The next panel contains the Power Company's watthour meter and graphic 15 minute demand meter, the two control wattmeters for the peaktaking systems, control switches for the 60,000 volt lines, test links and overload and ground relays. The next two panels are for number 13 and 14 banks of transformers with the various meters, relays and control switches as shown. The following six panels are for the outgoing feeders, each containing ammeter, wattmeter, power factor, control switch and CZ relays. The last panel is for a radial feeder to the Beam and Column Shop.

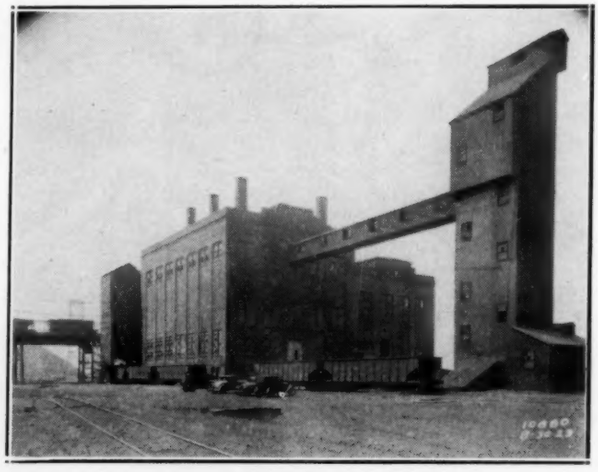


FIG. 8.

The station also has an emergency battery with an operating voltage of 250 volts for closing and tripping the various oil switches in case the power goes off. There is also a small motor generator set for charging this battery.

The station is normally operated with one trunk from the Power Company feeding the station transformers, all of which are parallel on the 60,000 volt side. The two 60,000/6600 banks of transformers are paralleled on the 6600 volt bus through two oil switches D-38 and D-41. The third switch D-37 is kept as a spare. All feeders are normally kept in service.

The power at this station is transmitted over the plant loop system and is paralleled on the 6600 volt bus at No. 2 Power Station which is the plant's own generating station.

The load operation of the station will be described later in conjunction with the operation of No. 2 Power Station.

No. 2 Power Station

No. 2 Power Station is located on the Ship Canal at the North end of the plant about two miles from No. 3 Power Station and is shown in Figure 8. This station consists of two Curtiss Steam Turbines, 7500 and 12,500 KW, which operate in parallel with the transformers at No. 3 Power Station and take the peak load from No. 3 Power Station through the mill peaktaker system operating on the slip regulators of the induction motors at the mills and later operating direct on the turbines.

The turbines supply 20% of the total power used by the plant and carry an average load of 4800 KW, with 15 minute demands up to 17,280 KW. The load factor based on the 15 minute demands and the average KW load is 31.2%.

Power from the turbines is normally supplied to an "A" and "B" bus, but can also be supplied to a third or emergency bus. The "A" bus is used to carry the important loads of the station, such as the main pumping station, the power transformer which supplies power to the station auxiliaries, including the turbine exciters, a motor generator set supplying power to the direct current station auxiliaries such as the stoker motors, and the 6600 volt Coke Oven Substation feeders. The "B" bus carries the four station feeders tying in with the plant transmission system.

Normally, one turbine is placed on the "A" bus and the other on "B" bus and the two busses are then paralleled through a tie switch so that in case of an interruption of power, the "A" bus can be separated from the "B" bus and thus maintain voltage on the equipment mentioned above.

Viewing Figure 8, the coal handling building is on the right, the boiler room is in the foreground and middle of the picture and the turbine room having the lower roof is just back of the boiler room. The operating room is back of the turbine room but is not shown in the figure. The ash handling house is to the left of the boiler house.

The boiler house contains six Babcock Wilcox Company type WSVH design, wrought steel, sectional water tube boilers with longitudinal drums and horizontally inclined tubes. Boilers 1-4 are rated at 763 HP and boilers 5 and 6 at 1018 HP and operate at 250 lbs. pressure and 200°F Superheat.

Coal is brought from the coal house to the hoppers above the boilers by a belt conveyor. From the hoppers, it is brought down by means of a chute to each of the boilers which are face to face, three on either side of the center of the room. The chute can be swung by hand through a radius such that the coal can be placed on the entire width of the stokers. The stokers are Riley self dumping under feed type with two speed gear boxes and are driven by 20 HP, type SK, 400-800 R.P.M. 230 volt motors. All boilers are operated under forced and induced drafts.

There are two turbo generators in the room as shown in Figure 9. No. 1 turbine has an overall length of 31′, width 12′10″ and a height of 10′8″ and weighs 290,000 lbs. The steam at the throttle is 250 lbs. and 200°F Superheat. The back pressure in the exhaust chamber of the turbine is 1½″. The speed regulation is 2% for a change in load of ½ the rated load.

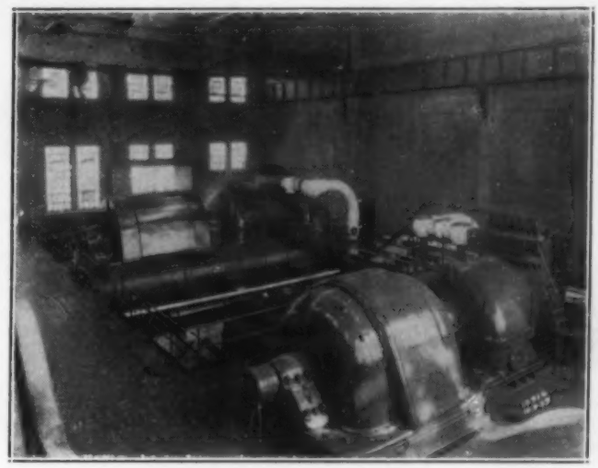


FIG. 9.

The generator of the set is 3 phase, 25 cycles and rated 9350 KVA, 7500 KW, 8 P.F. 1500 R.P.M. 6600 volts, 820 amperes per phase at 80% power factor. The excitation is 125 volts, 60 KW. An air washer and cooling fan supplies 25,000 cu. ft. of air per minute. The armature will stand 14,200 volts and the field 1500 volts. For the following KW outputs of the Generator, 1875, 3750, 5625, and 7500 KW, the water rate on the turbines are 13.95, 12.35, 11.85 and 11.95 respectively.

No. 2 Unit shown on the left side of Figure 9 was started in April 2, 1921, and is 34′6″ long, 13′9″ wide and 12′9″ high and weighs 430,000 lbs. The steam at the throttle is 250 lbs. and 200°F superheat, and the back pressure 1½″.

The generator is 3 phase, 25 cycles, rated at 15,625 KVA, 12,500 KW at .80% Power factor, 1500 R.P.M. 6600 volt and amperes per terminal 1370. The high voltage test on the stator is for 14,200 volts and on the rotor for 1500 volts. For the following KW outputs of the generator, 3125, 6250, 9375, and 12,500 KW, and a back pressure of not greater than 1½″, the water rates on the turbine are 13.4, 11.9, 11.6 and 11.8 lbs. respectively and for a 28″ vacuum, they are 14.0,

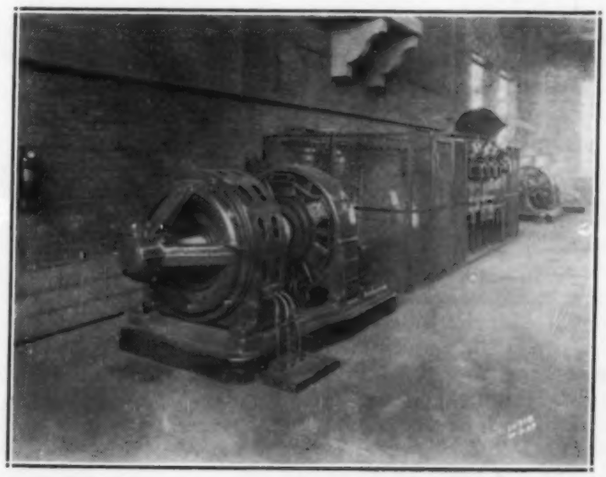


FIG. 10.

12.4, 12.05 and 12.15 lbs. The efficiencies at full load, three quarter and one half loads at 80% Power Factor are 90.2, 96.0, and 94.2%, and at unity power factor, 97.2, 96.6, and 95.2%. An air washer and cooler supply 36,000 cu. ft. per minute.

After the steam has passed through the various stages of the turbines and the condensers, it is passed back into the feed water heater and into the boilers. The 7500 KW turbo generator has a 92" Wheeler surface condenser and the 12,500 KW turbine, a 120" surface condenser.

The generator fields are excited by means of the two motor generator sets shown in Figure 10 which are on the same floor as the turbo generators. Power for the motors is taken from the 440 bus of the 6600/400 volt auxiliary transformers connected with the station. The exciter sets are both General Electric, two unit, three bearing type. The motor is a 4 pole, 225 HP, 440 volt, 750/730 R.P.M. and primary amperes 280. The motors are controlled from the operating room and are started through compensators.

The generators are compound wound, 6 pole, 150 KW, 125 volts, 750/730 R.P.M. 1200 amperes. The generators will carry 150 KW continuous with 40° rise and 25% overload for 2 hours with 55° rise. The generator circuit breaker panels are shown between the two exciter sets in Figure 10 and consist of solenoid operated air circuit breakers and knife blade disconnect switches.

In the turbine room is also located a 1000 KW motor generator set which supplies power for the station D.C. load and also ties in with the plant 250 volt system. On the turbine floor, but under the switching gallery, are the cell structures for the disconnect switches and oil switches. In the basement under the cell structure is located a 900 KVA transformer bank which supplies power to the station equipment and is also tied in with the plant 440 volt system. The transformers are single phase rated at 6600/2200 volts on the primary and 440 volts on the secondary, 55°C rise on continuous load and contains 520 gallons of oil each. At present, the transformers are connected for 6600/440 volts.

The operating floor mentioned above contains the turbine oil switches and the control room, shown in Figure 11. Power is brought from the turbines to disconnect switches and oil switches, type FH-203 rated at 15,000 volts, 1200 amperes, continuous with interrupting capacity of 39,300 amperes at 6600 volts, 60,000 amperes for 5 seconds, 125 volt control, for the 7500 KW turbine and a rating of 1500 amperes for the 12,500 KW turbine.

The section of the control room for the turbines and feeders is shown in Figure 12. The panels are benchboard type. The first panel on the left contains the switches for Nos. 1 and 2—6600 volt pumps and transformers. On the panel also, are ammeters for the above equipment, a synchroscope for phasing the turbo generators and two voltmeters, one for "A" bus potential and the other for "B" bus potential. Between the two voltmeters is the frequency meter. The graphic meters on this panel indicate the KW load on No. 1 turbine and the steam pressure of the boilers in lbs. per sq. in. The second panel is for the 7500 KW turbine and contains the generator field switch, the switches for putting the turbines on either "A" or "B" bus, voltmeter plug switch, the 440 volt tie switch, tying the transformer bus with the 400 volt plant system, and a signal system with the turbine room. On the vertical section of this panel are the various instruments used in conjunction with the turbine, namely, voltmeter, ammeter for the armature and field, wattmeter, power factor meters and a temperature indicator. There are two switches, a D.P.S.T. switch for the control circuit and a T.P.D.T. switch for the peaktaking system. With the T.P.D.T. switch in the up position, the turbine can be controlled by the hand operated governor control switch on the bench board and in the down position, the governor of the turbine is controlled through the contact wattmeter at No. 3 Power Station. In starting up the turbine, the motor operated governor control switch is used, which is between the control switch and the peaktaking switch. This is left in the full position when the control is changed over to the solenoid control of the peaktaking device.

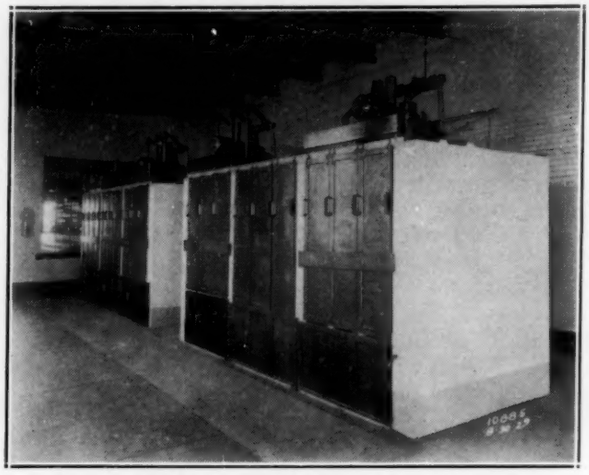


FIG. 11.

The third panel is for the 12,500 KW turbo generator and has similar equipment to that of the 7500 KW turbo. Between the two panels is the totalizing indicating wattmeter. The next three panels are for the station feeders and bus paralleling switch. The fourth panel bench contains four switches, one of which controls the bus paralleling switch, a General Electric type FH-203, 15,000 volt, 1200 ampere oil switch. Two other switches are for feeders tying in with the plant system and the fourth switch is a spare. The switches are all of the same rating as above. The panel contains two ammeters, one for each feeder and a wattmeter for each feeder. The graphic meter is the KW load for the 12,500 KW turbine.

The fifth panel contains similar equipment, although only the two upper switches are used for the two other plant feeders. Each line has an ammeter and the graphic meter shown, totalizes the load of the 7500 and 12,500 KW turbines. The sixth panel also has similar equipment, the two upper switches controlling feeders to the Coke Oven substation. Each line has an ammeter and a wattmeter for load indication and below these meters is a Westinghouse type OA, 15 minute demand meter measuring the demand on the two turbines. The lights at the top of panels 2 and 3 are two lights which indicate the operation of the peaktaking device showing whether No. 3 Power Station wants the load at that station picked up by the

turbines or reduced on the turbines. The other two lights standing vertically on these same panels indicate whether the mill peaktaking device is in operation and when the power peaktaking device is cut in on the turbines. In back of these panels, facing the wall is a similar set of vertical panels containing the overload relays and watthour meters for each turbine and each power line and station feeder and in addition, the contact wattmeters and the related relays and contactors for the peaktaking systems.

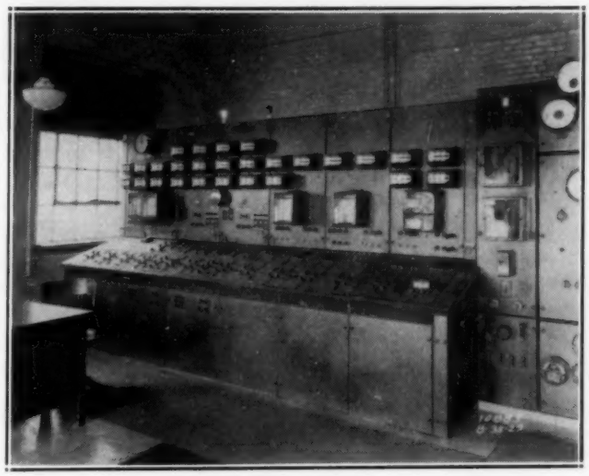


FIG. 12.

A section of the remaining panels in the control room is shown in Figure 12. The first two panels on the right of the figure are for the 1000 KW motor generator set. The first panel is the regulating panel with contactors, voltage and current regulators, field switches and rheostatic field control switches. The other panel contains the voltmeter, A.C. and D.C. ammeters and power factor meter, and starting and running control switches and the overload and undervoltage relays. The motor generator set was started by means of auto transformers but is now being changed over to reactor starting.

The next two panels which are not shown, contain ammeters, voltmeters, control switches and field adjusting switches for the two exciter sets. The fifth panel contains the regulator for the turbines which may be changed from "B" to "A" bus by the D.P.D.T. switch at the bottom of the panel. The graphic meters are for the 6600 volt bus potential and round type D.C. voltmeter for the generator on the 1000 KW motor generator set. The end panel contains 4 control switches for the D.C. feeders taken off the 250 volt and three D.P.D.T. switches for the exciter and battery control circuits. The contactor switches at the bottom of the panel are for automatically changing the control from the exciters to the battery in case of an interruption and for charging the batteries.

Under normal plant load, both generators carry the load simultaneously with the 12,500 KW turbine on "B" bus taking care of the General Plant load and the 7500 KW turbine on "A" bus carrying the emergency load of water pumps, Coke Ovens and station load. They are tied together through a paralleling switch E-7 between "A" and "B" bus, thus permitting the 7500 KW unit to take the excess load required of the 12,500 KW turbine. During an interruption of Niagara power, the entire plant load is thrown on the turbines so that in most cases the turbines cannot carry the load. In that case, the turbines are separated by opening up the paralleling switch E-7, if load was not heavy enough to pull plant feeders out which are set rather close to allow them to go out first, thus separating "A" and "B" bus. The emergency load is then carried by the 7500 KW turbine. The 12,500 KW turbine is cleared from "B" bus to allow No. 3 Power Station to come back on the load and then the turbines are phased in. If the turbines are able to maintain the plant load without separating "A" and "B" bus, No. 2 Power Station operator orders No. 3 Power Station operator to phase in at that station when he has power available.

The load regulation between the two stations is entirely automatic, although in cases of emergency, it may be regulated by hand. The procedure in adjusting the regulation is as follows:

At the beginning of each month the plant production in tons is given and the mill schedules are analyzed for load balance on day and night turns to give the most economical operation from an electric power viewpoint.

The relays for the automatic load control consists of two contact making polyphase wattmeters at No. 3 Power Station. They are operated from current transformers which are located in the incoming lines and may be shifted from one line to another by means of a F.P.D.T. switch. One relay is set to close its contacts at the predetermined value of the load that is to be carried on the Power Company's system for the month. The second meter is set to close its contacts at very light load and reverses the action of the first relay. This happens when power from the Falls is cut off and automatically opens the valves of the turbines to their maximum setting to take care of the increased load.

The contact wattmeters are connected by means of one of the two sets of lines going to No. 2 Power House, the other acting as a spare line, where they are connected to auxiliary relays. These relays formerly operated two single pole contactor switches which, when closed, energized the coil of the solenoid operated turbine valves, thus increasing or decreasing the load on the turbines. At present the auxiliary relays operate two normally open, definite time relays, which close two single pole contactor switches which are connected to a 250 volt source of supply. This feeds power to a control line which runs to the various mills having flywheel sets and slip regulators.

At these mills the lines are brought down to a small panel mounted near the slip regulator. Thus, when the peak value of power has been reached at No. 3 Power Station, it is reflected directly back on the flywheel set by operating a pair of single pole contactor switches which are normally closed and upon being opened, allow resistance to be inserted in the rotor of the torque motor which operates the slip regulator. This, in turn, slows the induction motor down by utilizing the energy stored in the flywheel during the period of the peak load. If the peak load is sustained at No. 3 Power Station at the same time the energy of the flywheel is being used, the auxiliary relays close another pair of single pole contactor switches which operate the solenoid switch for the valves on the turbine thus picking up the load. The

contactors may be connected so that they operate both turbines simultaneously or so that one turbine is operated up to a certain load by means of another contact wattmeter, the other turbine picks up the remaining load. When the load drops off, the process is reversed and No. 3 Power Station builds up its load again. In this way, the maximum fifteen minute demand values on purchased power, after once being set up, is maintained at this value throughout the month.

The entire adjustment of the load, after the value for the month has once been established, is made automatically as described above, and the method has worked satisfactorily within close limits. In addition, to get the very fine adjustments, the operator is required to "hit the mark" for each 15 minute demand of his turn. This requires continual checking of the loads on the station as coming either above or below the mark means a loss of money. The operators adjust the dial of the contact wattmeters at No. 3 Power Station so that the required value of demand is reached and there is an alarm which sounds a few minutes before the demand, registering pen resets, thus calling for a final adjustment of load to give or take more for the last few minutes. The operators also plot a 15 minute demand chart which tabulates their efforts.

Readings of all recording wattmeters are taken at 12:00 Midnight by station attendants each night and sent to the Electrical Superintendent's office the following morning on standard station log sheets, together with any details of power trouble that may have occurred during the operator's turn. At the same time the graphic KW meter charts are sent into the office and are available for the study of mill operation.

The installation of graphic demand and indicating recording meters at all prime power stations within the plant, gives an accurate distribution of power to each department, as well as pointing out the stations which are subject to heavy power demands. High demand stations are balanced, on the day and night turns with more or less continuous load stations to give the best load condition.

The main object is to reduce the composite cost of prime power and from a prediction at the beginning of the month, strike a balance between purchased and generated power. This will bring about an economical operation in both stations and allow a predetermination of a bogey cost of power for each month, rather than a post analysis of figures. Under this type of operation the cost of prime power has been continually reduced.

No. 1 Substation

This station is located west of No. 2 Open Hearth. Its generating equipment contains only two A.C. 1250 KVA, 2300 volt, 1500 R.P.M. generators driven by a steam turbine and one 500 KW, 250 volt, 100 R.P.M. Steam engine driven generator. At present the engine driven D.C. 500 KW generator is used for giving emergency 250 volt D.C. power to each of the motor rooms over a separate transmission line in case of a complete interruption of power. At the same time the generator is connected with the D.C. Feeders to the Open Hearths to carry the crane load, thus preventing the loss of a heat from a furnace during a complete A.C. power interruption.

In the present layout and operation, No. 1 Substation contains two motor generator sets with motors rated at 1440 KVA, 6600 volts, 375 R.P.M. and the generator a compound type, 1000 KW, 250-275 volts and one set with the motor rated at 720 KVA, 6600 volts, 500 R.P.M. and the generator a compound type, 500 KW, 250-275 volts. Each set is brought up to speed by a wound rotor, 440 volt, 375 R.P.M. starting motor and synchronized on the bus from the control panels by the station operator. The sets were previously operating on 2200 volts but the windings were changed over for operation on 6600 volts and 6600 volt type OE-6 oil switches installed.

The three sets feed a common station bus which is tied in with the 250 volt plant system. In all, there are twenty feeders going out of the station to No. 2 Power station, No. 2 Substation, the Docks, Open Hearths, Blast Furnaces and Shops.

The transformer equipment consists of a bank of three single phase, 25 cycle transformers, delta delta connected, oil insulated, self-cooled type rated 1000 KVA, 6600/2200 volts, efficiency 98.6%. The transformers are used as a tie transformer bank between the 6600 and 2200 volt loop systems. At present the 2200 volt loop is divided between No. 1 and No. 2 substations so that this bank is used to supply No. 10 Mill load over four underground feeders connected to 10 Mill bus. The second bank of three transformers is located next to the swing bank and are Pittsburgh transformers, delta delta connected, oil insulated, self-cooled type, rated 1000 KVA, single phase, 25 cycle, 6600/460 volts with a 230 volt tap, efficiency 98.5%. The transformers supply the 440 volt station bus. The third bank is located at the south end of the station and are delta delta connected, oil insulated, self-cooled type rated 375 KVA, single phase, 25 cycles, 2200/440 volts, efficiency 97.8%. These transformers also supply the 440 volt station bus.

From the 440 volt station bus, a large number of feeders are tapped to feed the blast furnaces, mills and shops. At present, these switches are grouped together in sections and 2000 amperes I.T.E. circuit breakers are used to control the lines.

The station also serves as a switching terminal for the 6600 volt loop system since the four underground lines from No. 2 Power Station, two lines from No. 1 Mill Bloomer and one line from No. 2 Substation are brought to the station bus and the two underground lines to No. 1 Mill Finisher are tapped off the bus, in addition to the above mentioned 6600 volt transformers and motor generator sets. There are an "A" and "B" bus similar to that at No. 2 Power Station so that the lines and station loads may be placed on either bus according to the condition encountered.

No. 2 Substation

No. 2 Substation is located in the west central part of the plant and has three motor generator sets, two banks of transformers, and oil switch and panel equipment for eleven transmission lines. The station is normally not manned but when the motor generator sets are put in operation an attendant is placed in the station.

Each motor generator set consists of a 720 KVA, 2200 volt, 500 R.P.M. synchronous motor and a compound wound generator rated 500 KW, 275 volts. The sets are brought up to speed by the 440 volt

starting motors and are synchronized on the line by the operator. The Sets are used only in case of an emergency.

Both of the transformer banks are delta delta connected, oil insulated, self cooled, rated 375 KVA, single phase, 25 cycle, 2200/440 volts. The transformers are paralleled and connected to the station bus through a 2000 ampere I.T.E. circuit breaker which in turn is connected to the 440 volt plant system.

The 6600 volt bus in the station is in the form of a square with disconnect switches in the centers of three sides of the square. These switches are normally left open, thus forming three sections of bus with lines feeding each section. The power is continually flowing in either direction over these lines according to the location of the load center at any particular instance.

High Tension Transmission System

The high tension system as shown in Figure 6 is built up of several interconnecting loops and radial feeders, so arranged that any section of line can be isolated from the system without disturbing the service to the rest of the plant. The system contains approximately 200,000 ft. of wire on the 6600 volt network, including 16,000 ft. of 3 conductor lead covered stranded copper underground cable; and 45,000 ft. on the 2200 volt system, including 18,000 ft. 4/0 lead covered cable. These lines connect 19 mill and substations with the two Power Stations for their sources of supply and delivery.

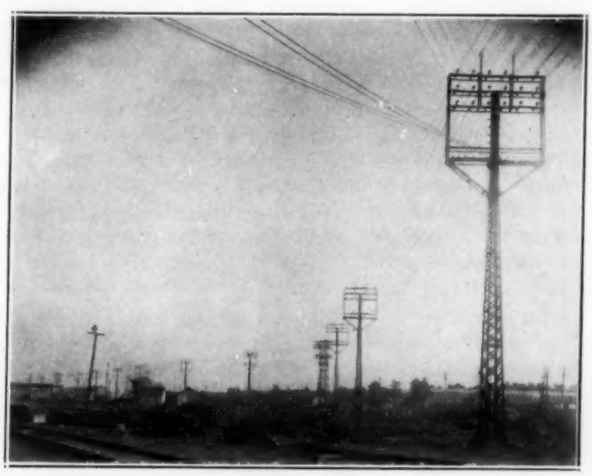


FIG. 13.

The overhead lines are mounted on steel towers, the average height being about 50 ft. Figure 13 shows the towers for lines leaving No. 3 Power Station.

The "flat" spacing is most generally used for the lines, the distance between wires, both horizontal and vertical, being 30". Several of the lines have the triangular spacing. The minimum distance between wires on the cross arm being 28" and the cross arms being 27" apart. For long spans over canal, triangular spacing is used, the minimum distance between wires on cross arms being 50", the cross arms 35" apart. All towers are connected by lightning protection lines and each tower is also grounded by means of a standard ground plate.

A line going into a station is carried down the side of the building and deadened through strain insulators to a steel cross beam on the tower. It is then carried through a porcelain wall tube into the station to a disconnect switch, thence through a choke coil to the oil circuit breaker and finally through another disconnect switch to the station bus. These disconnect switches, choke coils, busses and oil switches, are mounted in separate phase concrete cells with all openings covered by fireproof non-conductor doors. The jumpers between the disconnects, oil switches and bus are run through 4" fibre duct imbedded in concrete.

There are two types of disconnect switches used on the transmission lines. One is a single pole, single throw, single blade, 800 and 1200 amp. front connected switch; the other a selector type, single pole, double throw, double blade, 1600 and 2000 amp. top and bottom front connected, center back connected switch. When the former switch is used, the line is tapped to the top side of the switch and the choke coil and lead to lightning arrester is tapped to the bottom side. The lightning arrester circuit has a 200 amp. disconnect switch between the arrester and the lines. When the selector type is used, the line is tapped to the top side, the choke coil to back center and lightning arrester to the bottom side of switch with one blade in the down, and one blade in the up position. This type is used between the oil switch and the bus with the top side tapped to oil switch and bottom side connected to bus for incoming lines and vice versa for machine and transformer switches.

There are two types of oil switches in use on the lines, the Westinghouse 1200 amp. OE-6, 15,000 volt and the General Electric 1200 ampere FH-203-B, 15,000 volt circuit breakers.

The insulators for general use are the Nos. 25118, 23,000 volt, Ohio Brass with a few No. 5842, 33,000 volt Lapp fog pintype and No. 271, 35,000 volt Pyrex glass insulators in special locations. The cross arms are made from steel angles, the punching varying according to the spacing of the lines. The Hubbell steel insulator pin is used throughout the system.

Each line is equipped with two switchboards, one at each end. They are equipped with impedance relays, indicating wattmeters and ammeter, watthour meter, current and potential testing terminals, control switch for circuit breaker and indicating lamps.

Short Circuit Currents

A careful analytical study of the short circuit currents that occur on various sections of the loop system has been made as far as possible and checks on the short circuit tables of the Westinghouse and General Electric Companies have also been made. An analysis of the problem is not within the scope of this paper.

However, it has been found that with the present transmission system, transformer KVA and Synchronous KVA capacity, the ISC at .25 sec. varies from 8000 to 49,000 amperes, according to the location of the short. With the installation of the 30"-21" Sheet Bar and Billet mill, 18,000 KVA in synchronous motors and 15,000 transformer capacity will be added, making a total of 112,000 KVA to feed a short circuit. With this increase in KVA, necessary changes are to be made in the transmission system to limit the values of the short circuit current to within the interrupting capacity of the OE-6 and FH-203-B oil switches. The

solutions under consideration call for the introduction of reactors in several locations in the loop system.

The Mills

Extensive improvements to the Mills have been made in the last six or seven years. They included the changing over of the steam to electric drive on the 40″ Bloomer No. 7, 48″ Plate Mill and 12″ Bar Mill, and the rebuilding of the Rail Mill, replacing the steam Blooming mill by a 36″ Rougher and the addition of a new 44″ Bloomer to roll larger ingots. New structural mills installed were the 54″ Blooming and 48″ Finishing Mills, the 35″-28″ mill and the 18″-14″ Mill. At present, work is proceeding on the 30″ and 21″ Sheet Bar and Billet Mill. In the following descriptions, the mills are designated by numbers which signify the order of their introduction to the Plant.

Mill No. 1

44″ Bloomer
36″ Rougher
32″ Finisher

The 44″ Blooming mill and the 36″ Roughing mill each consist of a single stand of two high rolls. The 44″ Mill is driven by a 7000 HP, single unit reversing motor operating at 50 to 120 R.P.M. and the 36″ mill by a 5000 HP single unit reversing motor operating at 50 to 120 R.P.M. Both the 7000 HP and the 5000 HP motors receive power from the same flywheel set consisting of an 8000 HP motor and four generators. The 32″ Finishing Mill consists of two stands of two high rolls direct connected to a 7000 HP double unit reversing motor receiving power from a 5000 HP induction motor driving a two generator flywheel set. Figure 14 shows the layout of the 44″ Blooming Mill and Figure 15, the 36″ Roughing and 32″ Finishing Mills.

The charging cranes are 20 ton Morgan type with an 84′9″ span. Each crane is equipped with (2)—110 HP, motors in series on the bridge, a 40 HP motor on the trolley, a 140 HP motor on the main hoist, a 40 HP motor on the tongs, and a 10.5 HP motor on the compressors for opening the tongs.

The ingots are removed from the furnaces by the pit cranes and placed in the ingot chair in front of the delivery car, driven from the rear axle by a 250 volt, 70 HP,, 440 R.P.M. motor. The motor is operated through contacts sliding on four contact bars mounted along the east wall of the pit furnace building. At the north end of the tracks is a stop and a guide which tips the ingot chair to a horizontal position and drops the ingot on the transfer car.

The transfer car runs at right angles to the ingot car track and serves to transfer the ingots from the pit furnace building to the mill building. Power is received from 5 tiers of 2 rails each, placed below the surface of the floor and current is delivered to the motors through sliding contacts or a collector plow. An 80 HP, 230 volt series motor is used to drive the transfer car. There are 5 rollers on the table operated by a 50 HP, 230 volt series motor.

The ingot is again transferred to the mill approach tables, of which there are three, each driven by a 100 HP, 230 volt series motor and a part of which is shown in the foreground of Figure 16. The first approach table consists of 12 rollers, the middle table 10 rollers and the last table 8 rollers.

The front mill table is made up of 16 rollers. The housing rollers are driven by a 50 HP, 500 volt series motor. The east side guard is driven by two 180 HP, motors in series, and the west side guard by two 150 HP, motors in series. The manipulator fingers for turning the ingots are operated by two 70 HP, 230 volt series motors connected in series.

The Blooming Mill is a Bethlehem 44″, two high mill capable of rolling standard ingots. The screwdown machine is driven by two 100 HP, 90 MCA motors connected in series and located on top of the mill housing.

From the mill, the bloom is delivered to the back feed table with the same number and size of rollers and driven by the same size and type motors as on the front mill table. Leading to the shear table is the runout table consisting of 8 rollers of the same size and construction as the back mill table and driven by a 100 HP, 230 volt series motor. The bloom then passes over the north and south shear approach table. The north approach table has 15 rollers, driven by a 70 HP, 230 volt series motor.

The shear is a 100 ton capacity, steam hydraulic, up-cut machine with intensifier. It has a net shearing

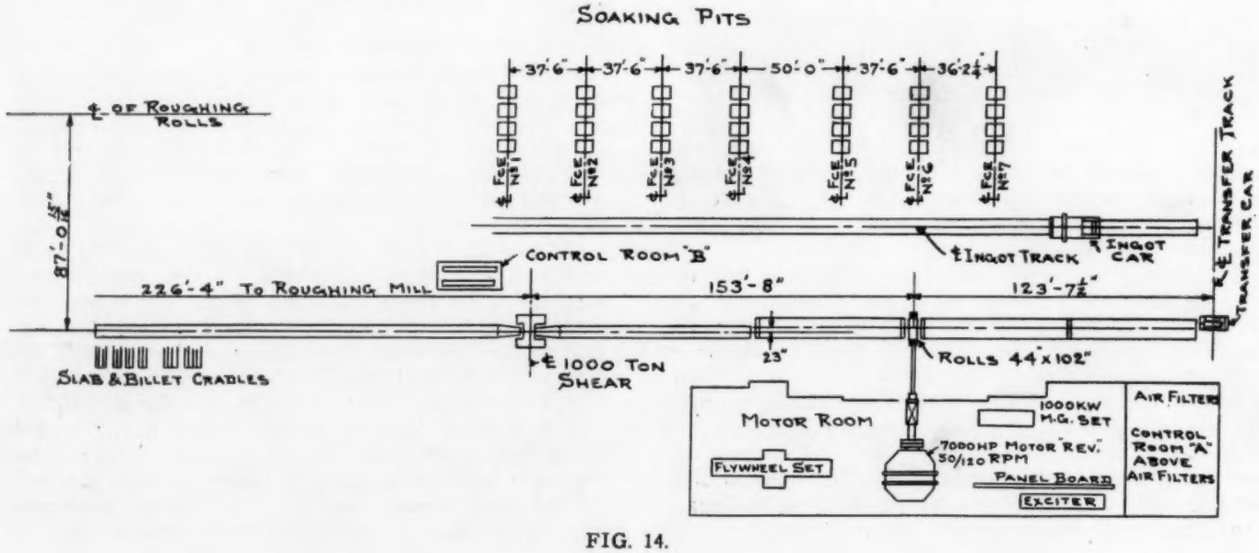


FIG. 14.

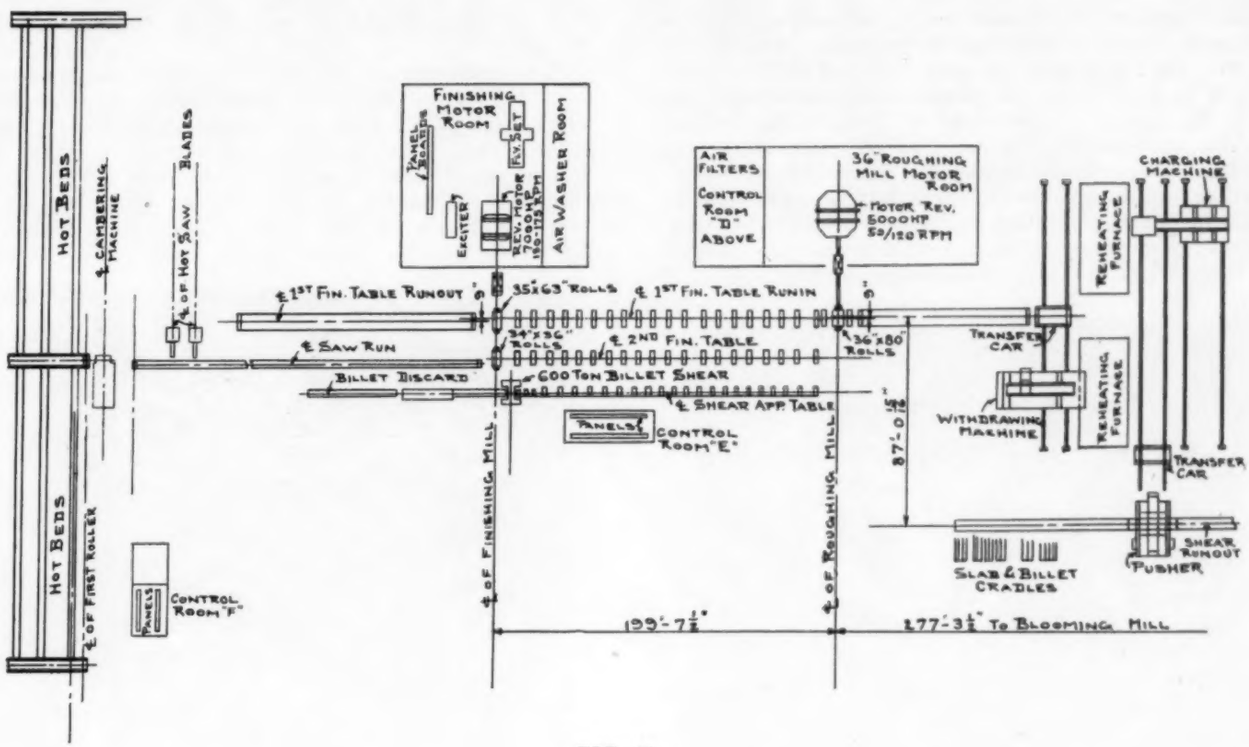


FIG. 15.

force of 1040 tons at 140 lbs. per sq. in. steam pressure and 880 tons at 120 lbs. sq. in.

The receding roller table consists of 16 rollers, which are moved down and away from the blades while the bloom is being sheared to allow the butts to drop through to a crop conveyor and are driven by a 50 HP, 230 volt motor. The drive on the pull back of the receding table is a motor similar in size and type to that on the table. The butts from the sheared bloom drop down to the lower part of the butt conveyor and are carried upward by flights on chains driven by an 85 HP, 500 volt motor and dumped into standard gauge cars. A 12 HP, 700 R.P.M. motor operates the crop conveyor chute.

The blooms or billets, while on the receding table, are run against the measuring gauge which is set to the length at which the bloom is to be sheared. The adjustment of the gauge is controlled by two 27 HP motors, one of which operates the gauge travel, while the other operates the gauge lift.

The second and third sections of the shear runout tables consist of 30 and 22 rollers respectively and are driven by a 70 HP, 440 R.P.M. motor, giving a surface speed of 381 F.P.M. The last roller of the 3rd section of tables is just beyond the stop for billets going to the reheating furnaces. If the bloom or billet is to be used in some other mill, it is carried over two more sections of roller tables leading to the billet cradle push-offs. These tables have 9 rollers each and are driven by 30 HP motors. The billet is stopped in front of one or the other of two billet push off tables by means of a disappearing stop operated by a 6 HP motor. The billet push off tables have 13 and 17 rollers respectively and are operated by a 30 HP, 475 R.P.M. motor. From these tables the billets are pushed off into the billet cradle, then they are loaded by means of a crane into billet cars and taken to the bar mills. The push offs are operated by 85 HP motors.

44" Mill

The reversing mill motor which is shown in Figure 17, receives its power from two generators to be described later and is a 24 pole motor with a normal continuous rating of 7000 HP at 50°C. rise and the speed ranges from 50 to 120 R.P.M. The voltage of the motor is 750 and delivers a torque of 735,000 ft. lbs. at 50 R.P.M. which corresponds to 7000 HP. As the speed is increased by weakening the field, the rated torque decreases to 306,000 ft. lbs. at 120 R.P.M. while the horsepower output of the motor remains constant at 7000 HP. These ratings are for continuous outputs when supplied with 50,000 cu. ft. of air per minute. Under such conditions, the temperature rise does not exceed 50°C.

FIG. 16.

As operated the current relays are set so that the motor develops 15,000 HP, or a torque of 1,660,000 ft. lbs. with full field giving a speed of 47½ R.P.M. As the motor speed is increased by weakening the field, the torque decreases to 591,000 ft. lbs. at 120 R.P.M. corresponding to 13,500 HP. For emergency conditions the circuit breaker is set to correspond to a maximum torque of 2,000,000 ft. lbs. at 46 R.P.M. and 17,500 HP. With an increase in speed by weakening the motor field, the torque decreases to 670,000 ft. lbs. at 120 R.P.M. corresponding to 15,500 HP.

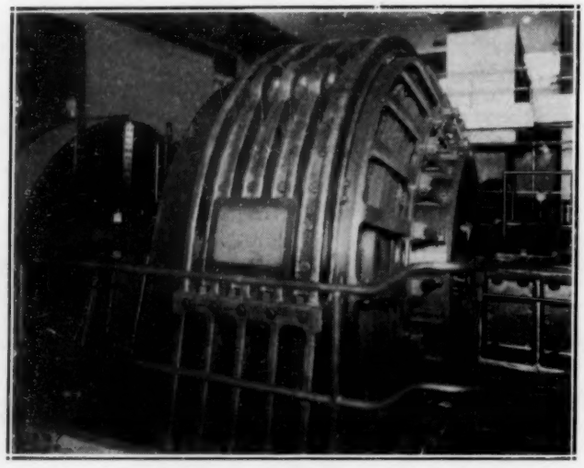


FIG. 17.

The guaranteed time for acceleration, deceleration and reversal are as follows: 0-50 R.P.M. .75 seconds, 0-120 R. P. M. 2.5 seconds, 50-0 R.P.M. .75 seconds, 120-0 R.P.M. 2.0 seconds, 50-50 R.P.M. 1.5 seconds, 90-90 R.P.M. 2.75 seconds, 120-120 R. P. M. 4.5 seconds.

The motor is built up on a cast steel base with the bearings supported by a cast steel pedestal bolted on the base. The pedestal on the coupling end is keyed to the base. The motor bearings are made up of a cast iron shell provided with a spherical seat, allowing free movement for self alignment, and they are split horizontally along the center line to allow removal. The lower halves of the bearing are provided with copper cooling coils. The bearings are lubricated by means of oil rings and are also supplied with oil from a gravity feed tank. The thrust bearing is enclosed in a housing and is so arranged that its surface bears against the babbited plate of the thrust bearing and is lubricated by the overflow of oil from the main bearing.

The motor is equipped with a centrifugal type limit switch and mounted on the pedestal bearing is a small separately excited D.C. generator geared to the motor. The generator armature is connected to the voltmeter mounted in the pulpit and is calibrated to read R.P.M. To prevent moisture gathering in the windings when mill is idle, there are electrical heaters in the pit of the motor.

The flywheel set which is common to the 44″ Mill Bloomer and the 36″ Rougher is located in the south end of the motor room and is shown in Figure 18. The set consists of 4 direct current generators, an induction motor and a flywheel, 61′4″ overall and mounted on a base 60′0″ long, 17′8″ wide and 12′8″ above the floor.

The unit driving the flywheel set is an induction type, 8 pole, normal continuous rating of 8000 HP. 50°C. rise, 375 R.P.M. 6600 volts, 3 phase, 25 cycle motor. The maximum running torque is 275% of normal or 290,000 pounds at one foot radius. The efficiency at full and ¾ load is 95%, while the power factor is 93.5% at full load, 92.5% at ¾ load and 90.0% at ¼ load.

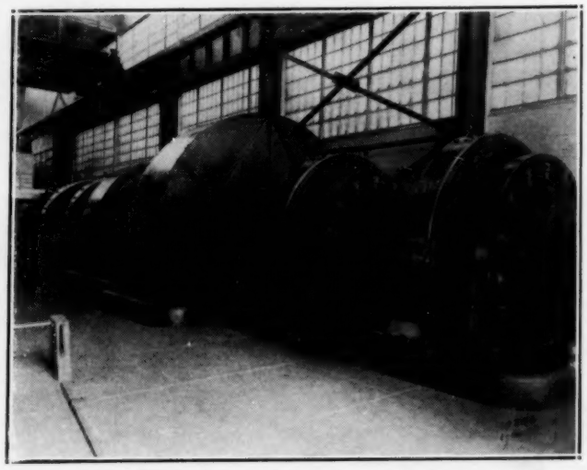


FIG. 18.

The stator is equipped with radial ducts for the ventilation of the windings and can be moved vertically or horizontally at right angles to the shaft for adjusting the air gap or can be moved endwise for rewinding. The windings are form wound open slots. The insulation on the coils is tested for 14,200 volts for 1 minute. The rotor winding consists of four separate copper bars per slot insulated with mica and held in place with wooden wedges and the ends are bound with banding wire.

The flywheel is cast steel 15′6″ in diameter, weighs 130,000 pounds and has a stored energy at synchronous speed of approximately 225,000 HP. sec. or a WK^2 of 5,150,000 lbs. ft.^{2} The total WK^2 of the flywheel set is 6,100,000 lbs. ft. or a stored energy in the set at synchronous speed of 265,000 HP. sec.

The two 3000 K.W. generators connected in parallel on one end of the flywheel set are used to supply current to the 44″ Reversing Mill and are duplicate machines and the two 2200 KW. generators connected in series on the other end are used to supply current to the 36″ Roughing Mill.

The generators are rated at 3000 KW each with a 50°C. rise in temperature; 16, pole, 750 volts, 4000 amperes, 375 R.P.M. separately excited. Both the armature and the fields are capable of standing 2500 volts between coils and frames for one minute. The efficiencies are as follows: Full load 93.25%, half load 93.0%, quarter load 92%. The generators have 15 brushes per stud with an area of 972 sq. inches giving a brush contact density of normal load motor current of 32.2 amperes with an average voltage across the bars of 15.6.

The main shunt fields are series connected and separately excited at 250 volts. In addition, there are commutating and compensating windings with magnet

frames made of rolled steel and split horizontally. The pole pieces are made of steel laminations bolted to the magnet frame. The armature spider is made of cast iron.

The slip regulator used in conjunction with the flywheel set is shown in Figure 19. The tank of the regulator is 12'0" long, 5'10" wide, and 9' high. It is filled with a solution of sodium bicarbonate. For driving the electrodes, there is a 40 ft. lb. torque motor operating from current transformers in the line side of the induction motor. The slip regulator controls the input when starting and plugging the induction motor and utilizes the flywheel with a fluctuating load by automatically regulating the amount of resistance in the rotor circuit. The regulator has sufficient capacity to dissipate continuously 10% of the rated output of the induction motor.

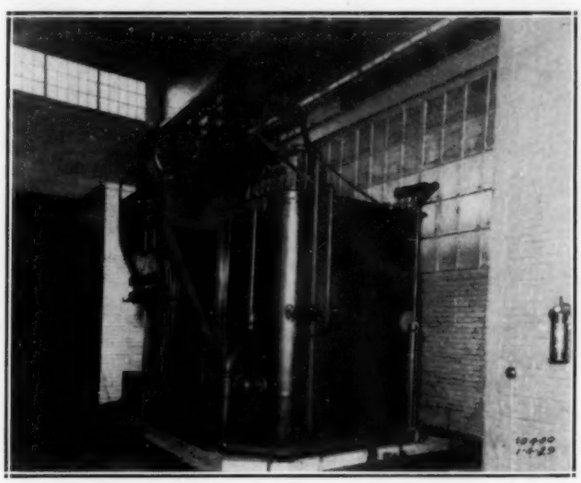


FIG. 19.

The combined D.C. Mill motor and D.C. Generator panel contains the following equipment: An ammeter for the motor armature circuit, an ammeter for measuring the unbalanced current of the generator, an ammeter for the motor field and generator field, a voltmeter for armature circuits and ground detection, a root mean square meter, a demand meter of 15 minute intervals, a graphic D.C. ammeter for motor armature current, a 10,000 ampere shunt for the graphic meter, a six point potential receptacle with 1-4 point plug and holder, a 6 point ground detector receptacle, a S.P.D.T. control switch with red and green indicating lamps, 250 volts D.C. and a ground relay.

The generator circuit breaker panels consist of two panels each with a carbon air circuit breaker, 750 volts, 8000 amperes, single pole with overload, shunt trip and undervoltage.

The control equipment for the 44" Blooming Mill in conjunction with the motor generator set is made up of a panel for controlling the field circuits of the generator and motor respectively.

The panel has mounted on it, 13 -300 ampere shunt contactors which provide for the reversing of the generator field; for forcing the generator field during the acceleration of the motor to basic speed; for eliminating the residual magnetism of the motor field to prevent the motor from creeping when the master switch is in the "off" position; and for speed regulation through the generator speed range. There are 4 -150 ampere shunt contactors providing speed rgulation throughout the motor field range, with various interlocks and undervoltage protection. A 300 ampere normally closed shunt contactor establishes and maintains discharge circuit for the generator field. There are 7 potential relays which provide potential control for the generator field forcing and prevent premature weakening of the field and reclosing of the main D.C. Breaker while voltage is maintained in the motor. To provide for a time adjustment between the various functions of the control, there are provided two magnetic type definite time relays and a 100 ampere D.P.S.T. fused switch which cuts in and out the power to the control circuit.

In the pulpit from which the 44" reversing mill is operated, there is a foot operated reversing master switch equipped with two foot operated pedals, which provide six-point control of the main mill. There is also a pedestal on which are mounted an ammeter with 20000-20000 ampere scale, a S.P.D.T. control switch for the circuit breaker with red and green indicating lamps, two S.P.D.T. control switches of the pull and push button type which are normally open and used for signal circuits, and an S.P.S.T. control switch of the pull button type which is normally open.

36" Rougher

The two generators on the south end of the flywheel set are connected in series and furnish current at 900 volts for supplying power to the 5000 HP. motor on the 36" mill, and are both rated at 2200 KW, 14 pole, 375 R.P.M. 450 volts, 4888 amperes, separately excited, 50°C. rise in temperature and efficiencies of 92.25, 92.0 and 90.75 at full load, ¾ load and ½ loads respectively. The insulation between coils and frame for both the stator and the rotor is capable of withstanding 2000 volts and is rated at a normal continuous load of 5000 HP. at 50°C. rise in temperature, 50 R.P.M. at normal full field speed and 120 R.P.M. at maximum speed. The motor delivers continuously a torque of 525,000 ft. lbs. at 50 R.P.M. corresponding to 5000 HP. As the speed is increased by weakening the motor field, the rated torque decreases to 219,000 ft. lbs. at 120 R.P.M. with the horsepower output remaining constant at 5000.

The current limit relay on the control equipment may be set at a current which allows the equipment to develop, during rolling, a torque of 1,000,000 ft. lbs. with full field on the motor and a speed of 47½ R.P.M. corresponding to 10000 HP. As the motor speed is increased by weakening the field, the torque at the current limit relay setting decreases to 354,000 ft. lbs. at 120 R.P.M. corresponding to 8100 HP.

To meet emergency conditions, the circuit breaker is set to a current which corresponds to the maximum torque of 1,320,000 ft. lbs. at 46 R.P.M. corresponding to 11,600 HP. When the speed is increased by weakening the motor field, the torque at the circuit breaker setting decreases to 425,000 ft. lbs. at 120 R.P.M. corresponding to 9750 HP.

The motor is rated 22 pole, 900 volt, 4400 amperes, separately excited, forced ventilation, with efficiencies of 92.0, 90.5, at full load, ¾ load and ½ loads respectively. The insulation on the armature and field withstand 2800 volts. The ventilating air required is 40,000 cu. ft. per minute. The guaranteed time for acceleration, deceleration and reversal of the motor is

as follows: -0-50 R.P.M. .75 sec., 0-120 R.P.M. 2.5 sec., 50-0 R.P.M. .75 sec., 120-0 R.P.M. 2.0 sec., 50-50 R.P.M. 1.50 sec., 90-90 R.P.M. 2.75 sec. and 120-120 R.P.M 4.5. sec. Figure 20 shows the 36" mill motor.

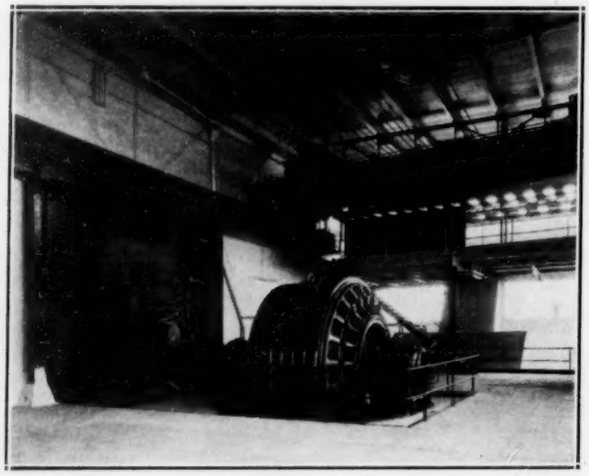


FIG. 20.

The combined panel for D.C. Generator and the 5000 HP. D.C. mill motor contains an ammeter for the armature circuit, a voltmeter for the armature circuit and ground detection, an ammeter for the motor field and generator field, a root mean square meter, a 15 minute demand meter, a graphic D.C. ammeter with a 6000 ampere shunt. The potential receptacle has 6 points with a 1-4 point plug and holder, a 4 point ground detector receptacle, a type R.G. ground detector, and an S.P.D.T. control switch with red and green indicating lamps.

The motor D. C. air circuit breaker is rated 900 volt, 8000 ampere, single pole breaker similar in style to the one on the 7000 HP. motor. The panel also contains a solenoid control relay, a trip free relay and an S.P.D.T. control switch with indicating lamps.

The equipment for motor and generator control for the 36" mill is a duplicate of that used on the 44" Bloomer motor and generators and the equipment in the pulpit is the same, except for the scale range on the D.C. ammeter for motor armature.

The exciter set for furnishing excitation for the various motors and generators consists of four 6 pole, 75 KW, 750 R.P.M. 250 volt shunt wound separately excited D.C. generators, 4 pole, 15 KW, 750 R.P.M. 250 volt compound wound, self excited generator and one 4 pole, 400 HP, 750 R.P.M. 220 volt induction motor. The entire unit is mounted on a common base with 9 bearings. The 15 KW generator supplies 250 volts for control, and excitation for the four 75 KW exciters. One 75 KW machine excites the 7000 HP motor, another the two 3000 KW generators, the third, the 5000 HP motor and the fourth, the two 2200 KW generators.

The exciter set panel is 15 KW, 250 volt capacity and contains the following equipment: A 100 ampere ammeter for the armature circuit and a voltmeter with a 4 point potential receptacle for the exciter, a 6 point potential receptacle for the generator fields, a D.P.S.T. 200 ampere, 250 volt field switch and a hand wheel and mounting for exciter field rheostat.

Power Supply

Power for the mill is brought to the motor room, a general view of which is shown in Figure 21, over four lines, two of which feed power from one direction to the bus and the other two feed power from the opposite direction, forming part of the plant loop system and thus permitting the power to come to the station in either direction over the lines. The bare copper wires enter the building through wall bushing type insulators, into separate cell structures built against the wall of the building for each phase of the line. The cable is brought down to type 800/5 current transform-

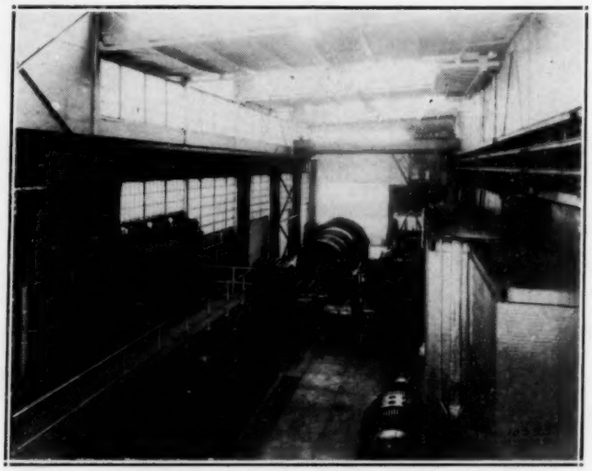


FIG. 21.

ers and then to 1000 ampere, heavily braced, 6600 volt, indoor type choke coils. The disconnects inserted in the line are S.P.S.T. 15000 volt, 800 ampere, front connected on metal bases with another blade used as the disconnecting switch for the lightning arrester, which is the same type as above, except that it is 200 amperes in capacity. The lightning arresters are of the oxide film, three phase, 6600 volt indoor type.

The lines are taken from the lower side of the disconnect switches to the oil switches mounted in separate cell structures placed further out from the wall on the switching gallery. The oil switches are type FH-203-B Automatic T.P.S.T. 15000 volt, 1200 amps, poles in parallel, bottom connected with 250 volt D.C. closing coil and motor operating mechanism and 12 volt D.C. trip coil. Another set of disconnect switches similar in type to those on the line side of the oil switches are inserted after the oil switches. The only difference is that the switches are back connected to the metal bases. The cables are then taken to the station bus with phases mounted in separate cells, running the entire length of the switching equipment in the gallery.

The switchboards for the control of the oil switches are located in the center of the switchboard panels as shown in Figure 22, and are 725 amperes, 6600 volt capacity boards. Each panel contains an ammeter, indicating wattmeter, watthour meter, ammeter jack, S.P.D.T. control switch with red and green indicating lamps at 250 volts D.C. relays and current and potential test links and studs.

The lines to the Induction motor of the flywheel set are tapped off the station bus and taken to the disconnecting switches ahead of the oil switches which

are S.P.S.T. 15000 volts, 800 amperes. The bottom of the disconnecting switches are taken to a set of current transformers for the regulation of the Slip Regulator, 15000 volts, 800/5 amperes and then to a set of 15000 volts, 800/5 amperes for meters and relays. There are two oil switches, one for the forward direction and one for the reverse direction, type FH-203-B, automatic T.P.S.T. 15000 volts, 1200 amperes poles in parallel, bottom connected with 250 volt D.C. motor operating mechanism, a 12 volt D.C. Trip and interlocked so that only one switch can be closed at a time. From the oil switch, the lines go directly to the primary of the induction motor. The oil switches are mounted in separate cell structures on the switching gallery.

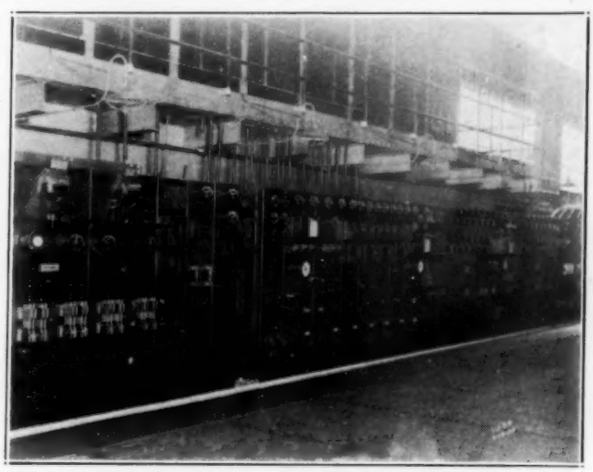


FIG. 22.

The panel for the control of the induction motor is to the left of the line switches as shown in Figure 22. Included on the panel are the high tension voltmeter, an indicating wattmeter, a demand meter, a graphic wattmeter, a potential receptacle, two control switches, one for the forward and the other for the reverse oil switch, red and green indicating lamps, an S.P.D.T. control switch for the heater circuit, a D.P.D.T. control switch of the push button type for the control of the slip regulator, a set of current and potential test links and overload relays.

The various motor auxiliaries are fed from a bank of three 25 cycle transformers, and which are equipped with filter press connections, dial type thermometer, weatherproof ventilators, oil gauge and sampling valve and are rated at 250 KVA each 6900/11950 volts on primary and 230 -115 volts on the secondary, and connected delta-delta.

36" Roughing and 32" Finishing Mills

The blooms from the 44" Bloomer which are to go to the rail mill are stopped in front of the push off to the reheating furnaces by a disappearing stop operated by a 6 HP motor. The push off to the charging car is run by an 85 HP motor.

The electric operated charging buggy is shown in Figure 23 and is mounted on standard gauge tracks. This car is operated from a master controller located in the cab of the charging machine and one extra contact bar is provided to carry the master circuit to the stationary controller. The buggy moves over the entire width of the two reheating furnaces, and is driven by means of a cable operating from a 70 HP motor located on the floor of the furnace room at the extreme end of the tracks.

The charging machine is also shown in Figure 23. It is a 8000 lb. machine capable of handling blooms 18' long. The machine is mounted on a 17' gauge track extending the width of the furances and consists of the bridge, ram and door lifting drives. The bridge is driven by two 40 HP motors operated from a controller in the cab and has a speed of 212' per minute.

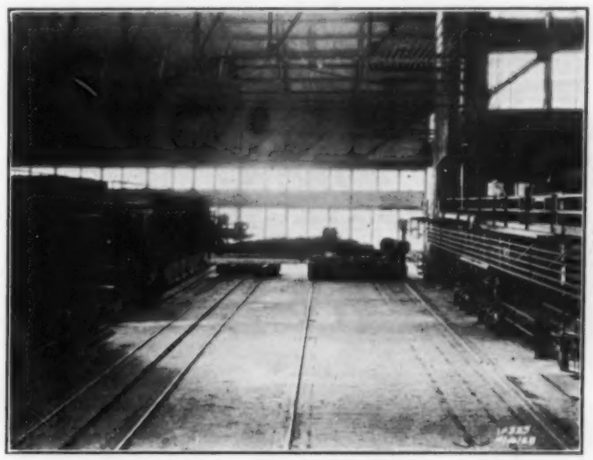


FIG. 23.

The trolley or ram support is operated by a cable drive and runs in stationary 12" H beams which act as guides, and form the trolley frame. At both ends of the frame, the cable runs over sheaves which are connected to a 40 HP. motor mounted on the charging machine and controlled from the cab. The ram arm is attached to the head of the trolley and has a pusher at the end which moves the bloom from the charging buggy into the furnace.

The door hoist is mounted on the furnace end of the trolley, and consists of a 6 HP. motor operating a worm on which is an arm rotating at a radius of 2'9". The arm on moving upward, strikes a projection on a casting which forms a part of the door equipment and to which is attached a cable at the upper and lower sides. The upper cable passes over a sheave at the end of which is a counterweight; the lower cable is attached to the door proper. With the door entirely open, the arm is just ready to release its hold on the projection on the casting, and when the bloom has been put into the furnace, the stroke of the arm is completed and the door is allowed to close, being balanced against falling too fast by the counterweight.

There are two reheating furnaces of the type shown in Figure 23. Each furnace is fed with coke oven gas and controlled by a valve, operated by a 6 HP. 230 volt D.C. motor located behind the charging machine and back of the furnace for which it controls the gas.

The withdrawing machine, shown in Figure 24, is a 8000 lb. machine mounted on a 40'8" span runway which runs the entire width of the furnaces and is capable of handling blooms up to 18' long. It consists of the bridge, trolley and door hoist drives. The bridge is operated by a 40 HP. motor at a speed of 212 ft. per minute. All motions are controlled from the cab.

The trolley is guided by 12" H beam sections and has a 23'2" stroke. The motor driving the trolley is a 40 HP. motor operating through reduction gearing which drives a series of sheave wheels drawing steel wire cable. The tongs from a part of the trolley and are closed to grip the bloom by the trolley drive cable through link connections. When the tongs grip the bloom, a pawl drops into position locking the grip and, to release, the pawl is lifted by a solenoid which is controlled by the withdrawing machine operator. The withdrawing machine pulls the bloom from the furnace on to the transfer buggy which transfers it to the Roughing Mill approach table.

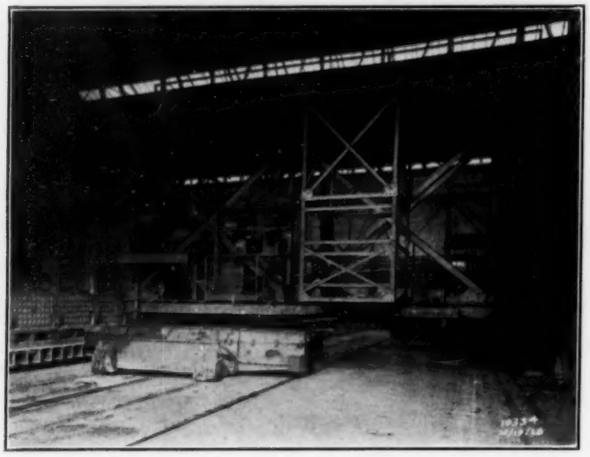


FIG. 24.

The transfer buggy is operated through a rope drive similar to that of the charging buggy and is made up of a section of roller table consisting of 7 rollers driven by a 30 HP. 230 volt motor mounted on the buggy. The bloom then passes over two sets of rolls, namely, the Roughing mill table with 6 rollers driven by a 70 HP, 230 volt D.C. motor and the front mill table with 14 rollers driven by two 100 HP, 230 volt D. C. motors in series. The manipulator for turning the bars on the front mill table is driven by a 70 HP, 230 volt motor.

The 36" Roughing Mill is a two high, reversing mill with pinion connected to the 5000 HP. motor by a leading spindle. The motor is located in a room on the west side of the 36" mill, as shown in Figure 20.

From the 36" mill, the blooms are conveyed over the rear mill table, similar in size and construction to the front mill table and driven by two 100 HP, 230 volt motors operating in series. The manipulator used in conjunction with the back table is similar to the one on the approach side of the mill and is driven by the same size motor. There is an intermediate table, between the last 9 rollers of the back table, consisting of 6 rollers and driven by a 40 HP, 500 volt armature operating on the 250 volt system.

The 32" Mill consists of two stands of two high rolls directly connected to an 8000 HP main motor which receives its power from a flywheel set consisting of two 2800 KW generators and a 5000 HP induction motor located in the motor room on the west side of the mill.. The product passes from this mill to the hot saws which are 46" drop frame type and driven by a 75 HP, 480 R.P.M. motor. From the hot saw, the rails pass through the cambering machine to the hot bed roller line. The hot bed extends the full length of the roller line and it is there that the rails are allowed to cool before being sent to the finishing building, containing the rail straighteners and drill presses. The finished rails are conveyed over a roller line in the center of the building to the loading shed where cranes place them in standard gauge cars for shipment.

The billets from the 36" rougher can also be transferred from the first finishing stand roller line to the shear approach table by means of a chain and sprocket transfer arrangement driven by a 70 HP, 230 volt series motor. 22 rollers of the billet approach table are placed at an angle to the center line of the mill to bring the billet in line with the shear. The remaining 5 rollers are straight and the entire table is driven by a 70 HP, 230 volt series motor.

The shear is 600 ton capacity and driven by a 125 HP, 480 R.P.M. motor. Used in conjunction with the shear, are the gauge lift and travel for measuring the length of the billet to be sheared each operated by a 28 HP, 470 R.P.M. motor. The finished billets are then pushed out on the billet transfer table by a pusher arm driven by an 85 HP, 480 R.P.M. motor. The billet transfer pulls them across the transfer table by means of a 50 HP, 75 R.P.M. motor drive. From here, the billets are loaded into the narrow gauge billet cars and carried to the various mills.

Power Supply

Power is normally fed over two underground cables from No. 1 substation where the oil switches are also located. The only switching equipment at No. 1 Mill is a set of disconnect switches for each line ahead of the station underground bus. The two station busses may be tied together through a set of disconnect switches, but they are normally open. Both the induction motor and the auxiliary transformer bank are tapped off the underground cable station bus.

The lines to the stator of the induction motor are taken through the line disconnect switches to both the FH-203 forward and reverse oil switches located under the switching gallery and then to the stator of the machine. The panel for controlling these switches is on the right of the switchboard in figure 25, and contains a voltmeter, ammeter, indicating and graphic wattmeter, watthour meter, control switches and an undervoltage relay. The auxiliary transformer lines are also brought through disconnect switches to an FH-203 oil switch and the transformer bank has its control switch and the watthour meter on the same panel that is used for the induction motor.

The second panel contains the meters, rheostat and control switch for the exciter set and, in addition, the control switches for the pumps and fans and the overload relays for both the induction motor and the auxiliary transformer. At the bottom of the panel, there is also a 15 minute demand meter for the induction motor of the flywheel set. The third panel contains the meters and control switches for the reversing motor, while the remaining panels contain the generator and motor relays and contactors to give the various speeds on the motor through foot switch control.

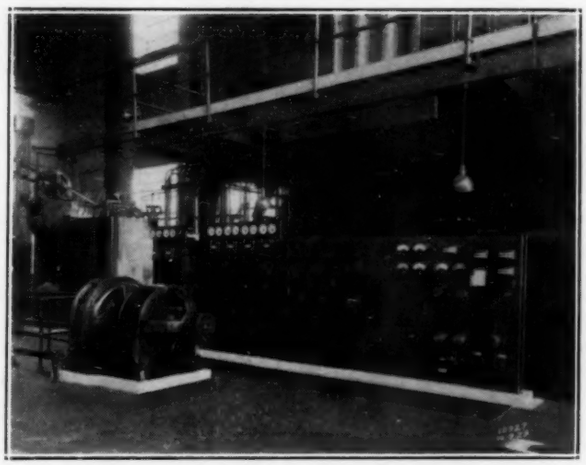


FIG. 25.

Motor Room

The flywheel set is shown in Figure 26. The motor has a normal continuous rating of 5000 HP at 35° C. rise 8 pole, 375 R.P.M. 364 amperes primary and 2020 secondary, 3 phase, 25 cycles and efficiency of 93.3% at ¾ and full load. It has a maximum starting torque of 225%.

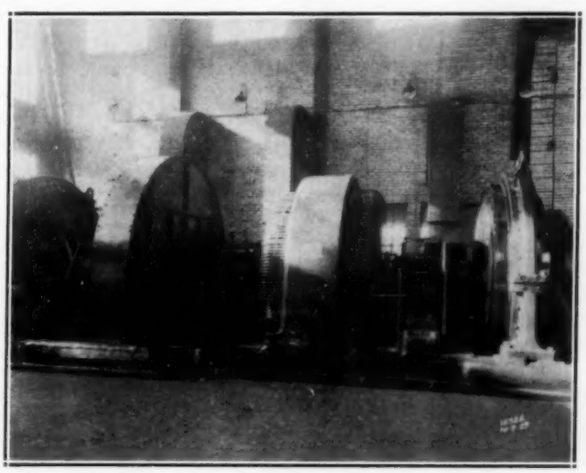


FIG. 26.

The stator is of the open slot construction and the frame has ventilating openings for the passage of air through and around the end of the windings. The stator can be moved both vertically and horizontally for adjustment of the air gap and likewise for rewinding.

The generators are rated at 2800 KW, 16 pole, 4670 amperes, 600 volts with efficiencies of 92% at one half load and 93.3% at full load. The frame is of cast steel, split horizontally.

The flywheel is 14′5″ in diameter and weighs 30 tons. It is a solid cast steel disc with two annular cast steel rings riveted to the outer surface, and has a steel plate covering.

Figure 27, shows the two unit reversing motors and the motor breaker panel. Both have oil ring and gravity feed oil lubrication and are equipped with cooling coils in bottom half of bearings. There are two motors mounted on the same shaft. Each motor has a normal continuous rating of 3500 HP with a 35°C. rise 16 pole, 150/175 R.P.M. 600 volt, 4700 amperes, separately excited with efficiencies of 91% at one half-load to 92.5% at full load. The total normal continuous rating of the two motors is 7000 HP at 150 to 175 R.P.M. The temperature rise with this load is 35°C. when supplied with 50,000 cu. ft. of air per minute. This rating corresponds to a torque of 245,000 lb. ft. and speed from 0 to 150 R. P. M. The torque at 175 R.P.M. is reduced to 210,000 lb. ft.

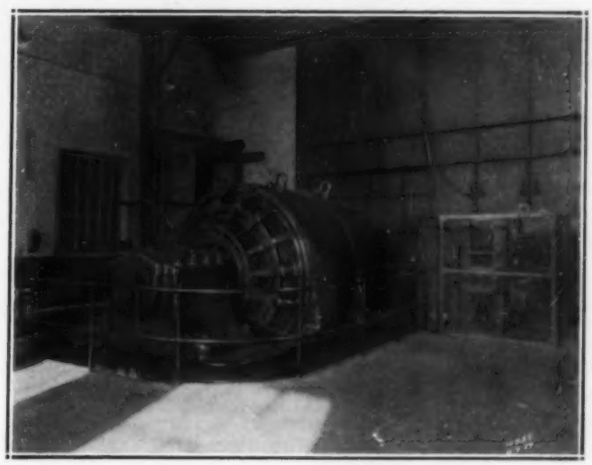


FIG. 27.

The two motors are capable of developing 12,200 HP at 140 R.P.M. and 10,500 HP at 175 R.P.M. for every ingot. This corresponds to a torque of 450,000 lb. ft. from 0 to 140 R.P.M. and the torque is reduced to 315,000 lb. ft. at 175 R.P.M.

In emergencies, the motors will develop a maximum of 17,000 HP at 140 R.P.M. and 15,500 HP at 175 R.P.M. These values correspond to a torque of 637,000 lb. ft. from 0 to 140 R.P.M. and at 175 R.P.M. the torque is reduced to 465,000 lb. ft.

The exciter set is shown in the foreground of the figure and is a two unit, three bearing set. The motor is a 4 pole, 150 HP, 750 R.P.M. 440 volt in-

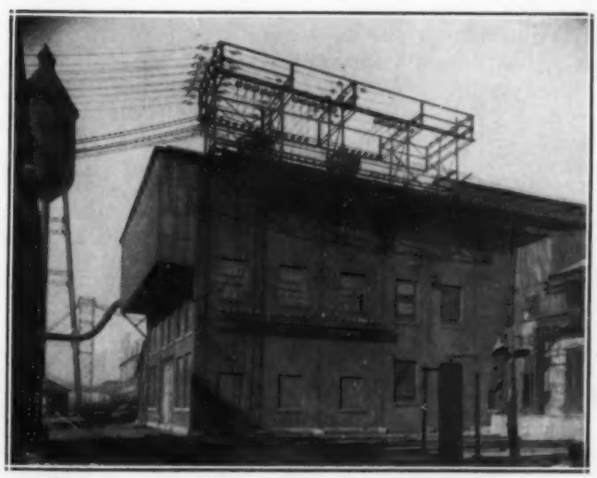


FIG. 28.

duction motor started through resistance in the rotor circuit. The motor is directly connected to the 6 pole, 100 KW, 250 volt, 400 ampere generator, which supplies the excitation current for both the generator and motor fields.

The auxiliary transformers are located in the basement of the motor room and are single phase, delta delta connected transformers rated at 100 KVA, 6600/440 volts with a 220 volt tap. These transformers supply the motors for the exciter set and for the fans and pump. The air supply for the flywheel set and reversing mill motors has a capacity of 50,000 cu. ft. of air per minute.

The operation of the drive is similar to that described for the Blooming mill, having slip-regulator control on the induction motor and a foot operated master control switch for the motor which is located in the pulpit outside the motor room. Motor speeds from 0-150 R.P.M. are obtained by varying the generator field, and speeds of 150-175 R.P.M. are obtained by weakening the motor fields.

In addition to the underground power supply, this motor room forms a switching gallery for one corner of the north loop of the transmission system and provision has been made to connect the underground bus in this room to the overhead transmission bus by means of disconnect switches . A 700 HP pump motor in No. 1 Pumping Station is connected to this bus over an underground radial feeder. Power is brought into this station bus by six overhead lines entering on the south side of the room as shown in Figure 28.

Rolling Mill Analysis

By E. KIEFT*

Euclid once said to his king, that "There is no easy road to Geometry," and I have often wondered, what he would have said, if the **Rolling Mill Problem** had been put up to him.

The rolling mill problem requires the finding of forces, work, energy, torque, velocities and accelerations in magnitude and direction when rolling different metals from one shape into another by means of two rolls driven directly or indirectly by a motor or engine. The problem therefore comprises many variables such as the friction between metal and rolls, between roll necks and bearings, etc.

We further deal not only with absolute, but also with relative non-uniform velocities and accelerations and the question of cooling time and temperature also comes into consideration, when dealing with several passes.

This complexity of variables, compared to which even the celebrated theory of relativity looks simple, may account for the fact that the writers of modern textbooks on mechanics and physics have left the problem alone. The Encyclopedia Britannica, which deals with almost everything scientific, has nothing to offer, although the rolling mill problem has been waiting for solution for centuries.

The reason why relativity cannot be used for solving above problem is that it uses non-Euclidean or fairy land geometry, which leads to the conclusion, that there is no straight line, and therefore forces us to believe that we cannot think straight. This will not work in reality, because nobody can figure out anything unless he accepts the reality of the straight line.

The engineering profession demands straight line mathematics, because it deals with realistic problems. No real engineer or scientist considers a problem solved unless he can present it in a common sense language and simple mathematics. They know that it is easy to express the area of a triangle by means of a wilderness of higher mathematics, but also that the common sense solution, "base times half the altitude equals the area" is the best and most attractive.

There exists a tendency in the human mind of trying to exploit things we do not understand by means of complex mathematics and grammatics. Take for instance the complex mathematics and grammatics of radio and other phenomena, before we were able to reduce it to very simple mathematics and common sense. The spooks and mystifications were eliminated one after another as soon as we went to work and started building something.

We come then to the final conclusion, that it is easy to explain the Rolling Mill Problem as soon as we have a "clear conception," i.e. as soon as we know what we are talking about.

For many years the writer has been occupied with steel mill work and rolling mill problems and has calculated loads and stresses by means of formulas, which covered part of the items involved in the problem, but not all of them. The results obtained could generally be checked by the input observed at similar equipment. This enabled him to use so-called safety factors, which produced fairly good results in actual practice. But there always remained a feeling of uncertainty, especially after reading so much variety of opinion on the subject as found in publications by authorities.

So he decided to make an attempt to put the problem on a common sense basis, which lead to the solution of the problem as represented by Figs. 1, 2 and 3, especially the Figs. 2 and 3, the key to the story. The one shows the balance of forces and the other the balance of the statical moments. Reducing the dynamic system to a static system was the difficult part of the job. The rest was easy, just like everything else after we know it.

The basis of the following calculations is that the temperature of the metal is uniform and therefore the stress the same for every square inch of contact between roll and bloom or billet. The density of the steel increases about 3% when rolling from ingot to bloom or billet. An ingot is called a bloom after

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it has passed once through the rolls. The bloom is called billet after its sectional area becomes less than 6x6 or 36 square inches. The rectangular shapes are called sheet bar, strip, band and plate, all according to manufacturers' rules, which are subject to change.

The required amount of work to compress the steel is distributed over several roll passes. The density therefore will be considered constant under normal rolling conditions, unless mentioned otherwise. This gives the basic equation for roll pass design and analysis; area times velocity equal a constant. The uniformity of temperature leaves no choice or doubt regarding the direction of the resultant force P_2 (Figs. 2 and 3), because the uniformity of temperature of the metal as required for obtaining uniform results or products gives uniform resistance per square inch of contact between bloom and roll. The reactions therefore are equal, consequently the resultant force must bisect the angle of approach.

This subject has been discussed in detail by the writer in the general outline of the analysis. He has shown that the temperature change due to abrasive resistance or to rolling resistance has comparatively no influence and also that the pressure increase due to accelerated compression does not affect the direction and magnitude of the resultant force P_2 at normal speeds as encountered during actual rolling.

"f" is the coefficient of friction required between bloom surface and roll surface in order to permit the bloom to enter between the rolls. Its normal value is .4 corresponding to $\theta = 22°$. The maximum value of θ varies between 20° and 35°, dependent upon the condition of the surfaces, the velocity of the bloom, and upon the ratio G_1/G_2 of bloom and roll. The value of "f" reduces at times to 0.1 on account of increased surface temperature due to slippage. The larger the roll weight as compared with the weight of the bloom the larger the percentage of impact energy is converted into deformation work of the bloom, with the result that the roll will bite much better under these conditions. A well known fact, frequently expressed by the phrase (which refers more to the weight than to the diameter)

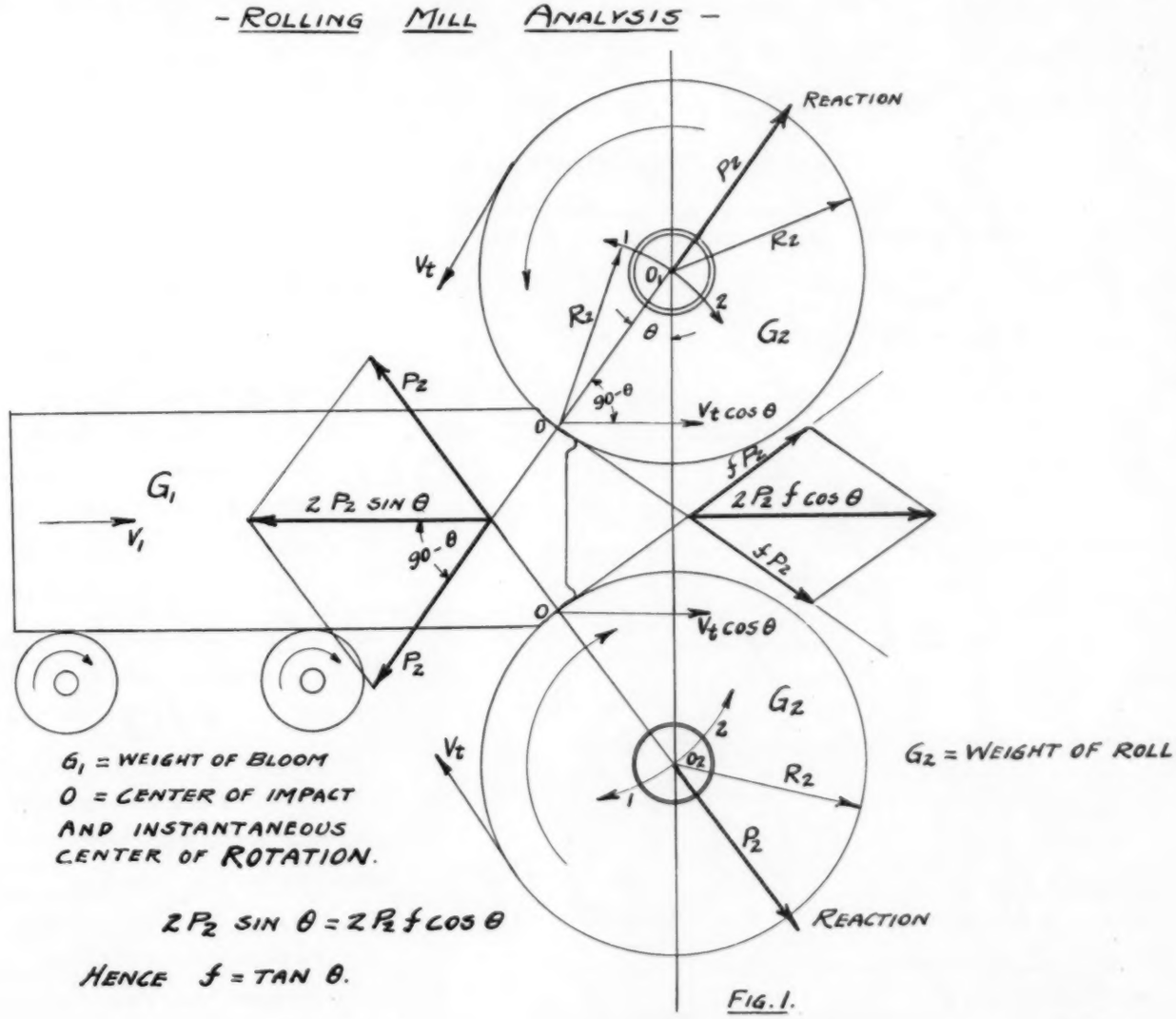


FIG. 1.

1. ANGLE OF APPROACH "θ" AND ENTRANGE OF BLOOM INTO ROLL

"The larger the roll the better the bite."

Reduction of angle of approach during impact period of bloom, due to V_o being larger than $V_t \cos \theta$.

Each roll is replaced by two equivalent hammers having the same moment of inertia. The retardation of the hammer m_1, during the first instant of impact between bloom and roll causes a tendency of hammer m_2 to swing the roll-necks against Pt. 1 of the bearings, which is confirmed in practice by evidence of wear at point 1.

Impact Energy and Impact Stresses

The periphery speed of the table rolls is sometimes as much as 50% in excess of the periphery speed of the rolls, which has the advantage of assisting the entrance into the roll pass, because higher table speed means a higher entrance speed of the bloom, which hammers against the roll and suffers some deformation which shapes the end of the bloom along the lines of contour of the roll surface with the result that the angle of approach and consequently the necessary friction required for entering is reduced as shown in Fig. 1.

Let $V_o = C_o V_t$ speed of the bloom before entering the pass

$V_1 = V_t \cos \theta$ the speed at entrance of the pass

C_o = Ratio of V_o and V_t.

The impact energy given up by the bloom per pass is then

$$E_i = \frac{G_1}{2g}(V_o^2 - V_1^2) = \frac{G_1}{2g} V_t^2 (C_o^2 - \cos^2 \theta) \text{ ft. lbs.} \quad 1.$$

This amount of energy is called the impact of the bloom against the rolls and is split up in two parts of which the first part

$$E_i \frac{G_1}{G_1 + G_2} = \frac{G_1^2}{2g\,(G_1 + G_2)} V_t^2 (C_o^2 - \cos^2 \theta) \quad 2.$$

is transferred to the rolls and lost as heat and the noise produced by vibrations, which are also responsible for strains and stresses in rolls, housing and bearings, resulting occasionally in breakdowns.

The second part of the available energy E_i is equal

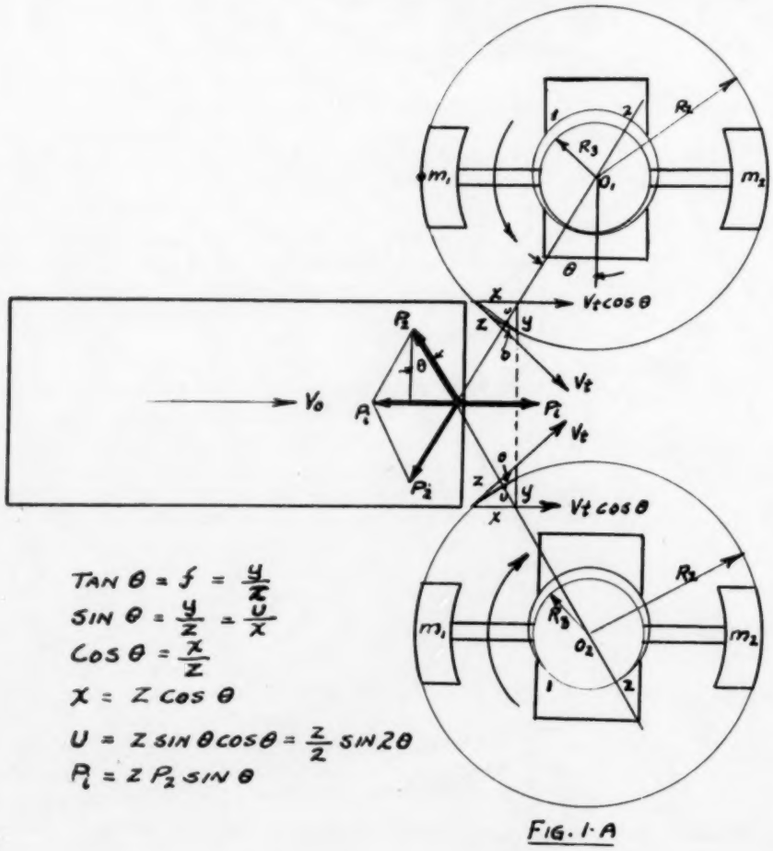
$$E_i \frac{G_2}{G_1 + G_2} = \frac{G_1 G_2}{(G_1 + G_2)\,2g} V_t^2 (C_o^2 - \cos^2 \theta) \quad 3.$$

And is used to a certain extent for deformation and shaping of the end of the bloom during the entrance period. The amount of energy used for deformation depends mostly upon the plasticity of the metal. The above formulae apply to non-elastic impact, therefore we can only expect a maximum amount of deformation when the metal is very hot, otherwise the formulae for partly elastic impact have to be employed which makes it worse for the entrance conditions and roll-pass stresses.

The centrifugal force of the rolls works against

- ROLLING MILL ANALYSIS -

REDUCTION OF ANGLE OF APPROACH DURING IMPACT PERIOD OF BLOOM, DUE TO V_o BEING LARGER THAN $V_t \cos\theta$.



TAN $\theta = f = \frac{y}{x}$

SIN $\theta = \frac{y}{z} = \frac{u}{x}$

COS $\theta = \frac{x}{z}$

$x = z \cos \theta$

$U = z \sin \theta \cos \theta = \frac{z}{2} \sin 2\theta$

$P_1 = z P_2 \sin \theta$

FIG. 1-A

WEIGHT OF BLOOM = G_1 LBS.

" " " ROLL = G_2 "

ROLL RADIUS = R_2 INCHES.

ROLL NECK RADIUS = R_3 INCHES.

R_2 IN FT. WHEN I IN FT. LBS. sec^2

g = ACCELERATION OF GRAVITY = 32.2 ft. PER SEC.^{2}

I = MOMENT OF INERTIA OF ROLL = $\frac{G_2}{2g} R_2^2$ ft. LBS sec^2.

$m = \frac{G_2}{4g}$ = EQUIVALENT MASS OF A HAMMER WEIGHING ONLY ONE QUARTER OF THE ROLL, THIS MASS IS SUPPOSED TO BE CONCENTRATED AT POINT m_1 AS SHOWN IN THE FIGURE.

I_m = MOMENT OF INERTIA OF EACH HAMMER = $\frac{G_2}{4g} R_2^2$, THEREFORE THE TWO HAMMERS HAVE THE SAME MOMENT OF INERTIA AS THE ROLLS.

the force available for deformation of the metal and is equal

$$F_c = \frac{12\, m_1\, V_t^2}{R_2} \text{ lbs. per roll}$$

From Fig. 1a we have $m_1 = \frac{G_2}{4g}$ Hence 4.

$$F_c = \frac{3\, G_2\, V_t^2}{g\, R_2} \text{ lbs.}$$

G_2 = Roll weight in lbs.
V_t = Periphery velocity in ft. per sec.
R_2 = Roll radius in inches.
g = 32.2 ft./sec²

The one half of the roll (m_2 Fig. 1a) is subject to tensile stresses due to F_c and the other half (m_1) to compression stresses when the metal is in the pass, due to P_2 being greater than F_c, this produces slight unbalanced conditions and therefore increased pressure on the roll-neck bearings.

At the first instant of the impact period we find P_2 smaller than F_c and the pressure between the bloom and roll is the equal BS dz in which

B = Width of bloom in inches
S = Stress in lbs. per sq. in.
dz = diff. of z(Fig. 1b)

Therefore at the first instant of the impact period

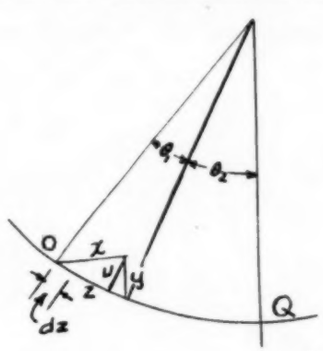


FIG. 1b.

we have $F_c - BS\, dz$ at m_1 and F_c at m_2, this causes a slight retardation of the speed of hammer m_1 and consequently a tendency of hammer m_2 to swing the roll necks against point 1 Figs. 1 and 1a. The point O becomes then an instantaneous center of rotation just like the point of contact between rail and wheel of a railroad car, which is also called an instantaneous center of rotation. A little slowing up of the railroad car gives the standing passenger also the sensation of being thrown forward like hammer (m_2). The small area of contact Bdz between bloom and roll increases to Bz during the impact period at the end of which the bloom stops pushing the roll and it is then up to the driving machinery to furnish the power.

The duration of the impact period is determined by the familiar equation: Available kinetic energy = resistance x distance

$$E_i \frac{G_2}{G_1 + G_2} = BzS \frac{u}{12} \text{ ft. lbs. per pass} \quad * \quad 5.$$

B = width of bloom in inches.
z = length of arc = velocity x time = $12\, V_t\, dt$ inches.
S = stress in steel in lbs. per sq. in.

$u = z \cos\theta \sin\theta = \frac{z}{2} \sin 2\theta$ in the triangle xyz (Fig. 1a), but z is really the length of arc and therefore u very nearly equals $y = z \sin\theta = 12\, V_t\, dt \sin\theta$.

This gives us by substitution of formula 1.

$$E_i \frac{G_2}{G_1 + G_2} = \frac{G_1}{2g} \frac{G_2}{G_1 + G_2} V_t^2 (C_o^2 - \cos^2\theta) =$$
$$E_i = 12\, BS\, V_t^2\, dt^2 \sin\theta.$$

$$\text{Hence } dt = \sqrt{\frac{G_1}{2g} \frac{G_2}{(G_1 + G_2)} \frac{(C_o^2 - \cos^2\theta)}{12\,(BS \sin\theta)}} \quad 6.$$

Let $G_1 = 16100$, $G_2 = 32200$ lbs., $C_o = 1.5$,
$\theta = 25°$, $\cos\theta = .906$, $V_t = 10$
B = 30", S = 5000#/sq. in., $\sin\theta = .423$
$\cos^2\theta = .82$

Then we find

$$dt = \sqrt{\frac{500 \times 1.43}{18{,}000{,}000 \times .423}} = \frac{1}{56.4} \text{ seconds.}$$

$$z = 12\, V_t\, dt = \frac{120}{56.4} = 2.13 \text{ inches.}$$

Average acting force during impact (See Fig. 1a).

$$\frac{dv}{dt} = \frac{V_t (C_o - \cos\theta)}{dt} = 335 \text{ ft./sec.}^2$$

BZS = 150,000 x 2.13 = 319,500 lbs. pressure between rolls and steel at the end of the impact.
Average acting force during impact

$$P_i = \frac{G_1}{g} \frac{dv}{dt} = 500 \times 335 = 167500 \text{ lbs.} \quad 7.$$

The foot lbs. work given up for deformation work during impact are found from

$$BSZ = \frac{u}{12}\, 319{,}500 \times \frac{2.13 \times .423}{12} = 23954 \text{ ft. lbs.}$$

Total energy given up by bloom was
$E_i = 250 \times 100\,(2.25 - .82) = 35750$ ft. lbs.

Impact efficiency $\frac{BSZU}{12\, E_i} = 66.9\%$ which should check the ratio $\frac{G_2}{G_1 + G_2} = \frac{2}{3} = 66.7\%$ as $\frac{G_2}{G_1 + G_2} E_i$ is the available deformation work.

During the impact period the bloom reduces the angle of approach from θ to θ_2 (Fig. 1b). The reduction is equal

$$\theta_1 = \frac{z\, 180}{\pi\, R_2} = \frac{57.3z}{R_2} \text{ degrees} \quad 8.$$

In our case z = 2.13, R_2 = 18 which gives θ_1 = 6.8° and θ_2 = 25 — 6.8 = 18.2°. This means that in this case the necessary friction coefficient is reduced

* Note—The equation five allows for extra resistance due to accelerated compression during the impact period, the right side of the equation (5) becomes only one half of the given value if we omit acceleration resistance. The above allowance holds only for ordinary rolling mill conditions.

Effects due to accelerated compression are discussed and put in mathematical form in the general outline on rolling mill analysis prepared by the writer for later publication.

from tan 25° to tan 18.2°, therefore the angle of approach is not only dependent on the friction coefficient and explains why in some cases θ is as high as 30° and also why there exist different ideas about the maximum angle of approach. If we had assumed $V_0 = V_t \cos\theta$ (Fig. 1a) then there would have been no impact energy available i.e., dt = o and f = tan θ = tan .25° = .4663 would be the minimum friction coefficient required in order to make entering possible.

The energy available due to the velocity V_0 of the bloom before entering the roll can partly be recovered as shown in previous example, but it should be remembered is based on the supposition that the bloom is straight and is rolling instead of jumping toward the rolls, in the latter case the impact energy is nearly all converted into noise, heat and strain in the rolling equipment, in fact better results would be obtained in such a case if the table speed was less than the roll speed, this means that the entering would be entirely dependent upon the coefficient of friction and driving power produced by the engine or motor.

Under normal conditions the tangential force $P_2 f$ comes into action as soon as contact is made with the rolls, this gives the well-known tendency of drawing the steel forward as shown in Fig. 1 increasing thereby the area of contact rapidly, with the result that the grip increases until the delivery starts i.e., when the metal has made contact with the full arc of θ and therefore the resultant force P_2 in the direction of $\frac{\theta}{2}$ (Fig. 2), because equal temperature demands equal stresses per sq. in. so that the resultant force becomes symmetrical, that is it bisects the angle of approach. The horizontal acceleration resistance, elongation resistance, abrasive resistance, and rolling resistance affect the magnitude of the tangential driving force $P_2 f_x$ but not of P_2 proper, therefore f_x is variable as expressed by the equations under Figs. 2 and 3: Theoretically there exists highly accelerated compression during the impact period, which increases P_2 above the value BSZ but said compression is comparatively small during the delivery period. The influence of the variable resistance is

ROLLING MILL ANALYSIS

2. CALCULATION OF THE NORMAL PRESSURE COMPONENT P_2, ITS DIRECTION ANGLE AND THE BEARING PRESSURE.

SUMMARY OF PRINCIPAL FORMULAE.

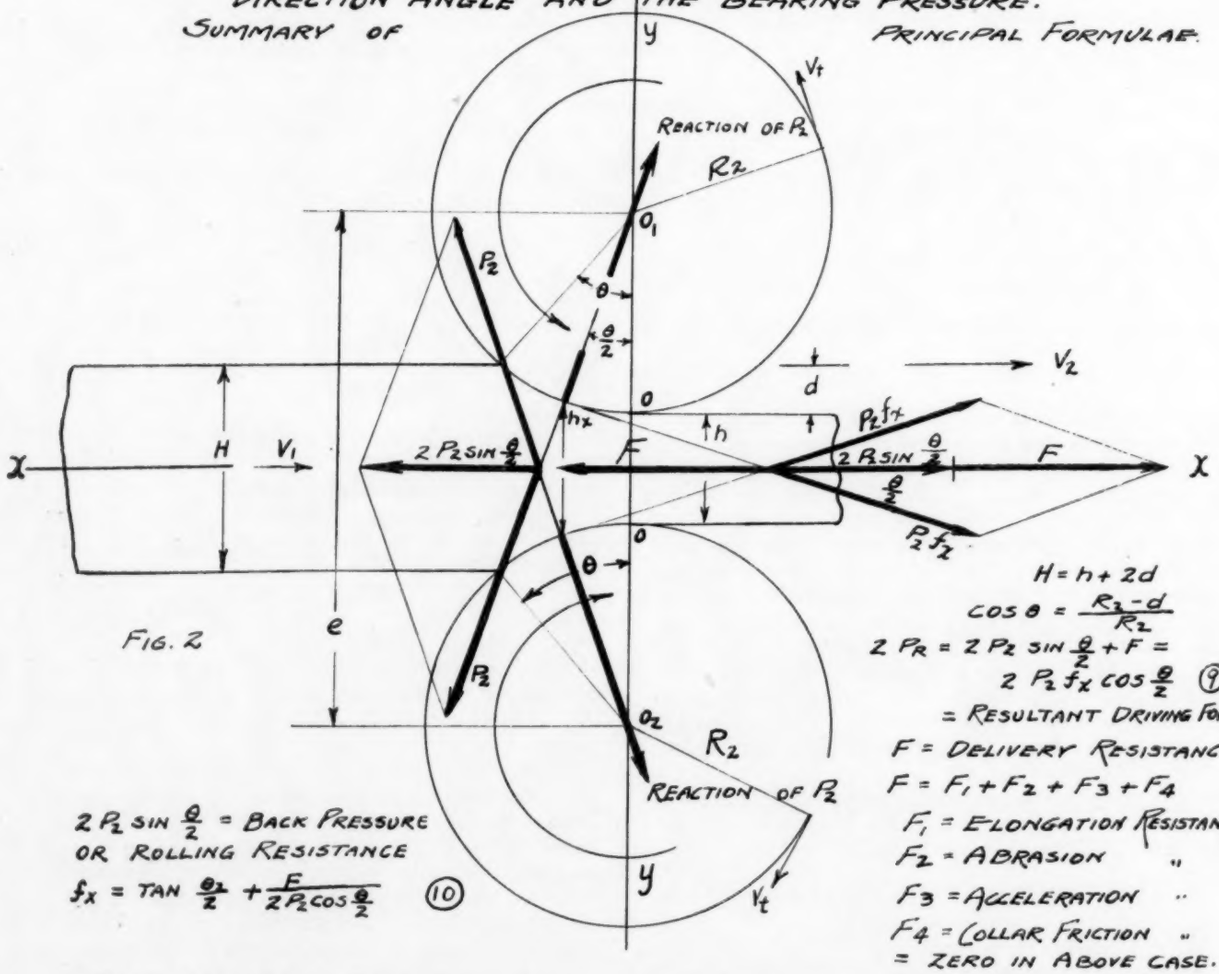


FIG. 2

$2P_2 \sin\frac{\theta}{2}$ = BACK PRESSURE OR ROLLING RESISTANCE

$f_x = \tan\frac{\theta_1}{2} + \frac{F}{2P_2 \cos\frac{\theta}{2}}$ (10)

$H = h + 2d$

$\cos\theta = \frac{R_2 - d}{R_2}$

$2P_R = 2P_2 \sin\frac{\theta}{2} + F = 2P_2 f_x \cos\frac{\theta}{2}$ (9)

= RESULTANT DRIVING FORCE

F = DELIVERY RESISTANCE

$F = F_1 + F_2 + F_3 + F_4$

F_1 = ELONGATION RESISTANCE

F_2 = ABRASION "

F_3 = ACCELERATION "

F_4 = COLLAR FRICTION "

= ZERO IN ABOVE CASE.

FORCE BALANCE DIAGRAM FOR CYLINDRICAL ROLLS OF THE FORCES ACTING ON THE BLOOM.

responsible for the delivery speed being not entirely uniform but slightly pulsating and is discussed in following pages.

2. Calculation of the Normal Pressure Component P_2, Its direction angle and the bearing pressure. Summary of principal formulae.

Force Balance Diagram for Cydindrical Rolls of the Forces Acting on the Bloom.

Action = Opposite Reaction

f_x = necessary coefficient of friction in order to balance the forces when delivering at a given speed V_2 given by formula 10.

f = available coefficient of friction .1 to .4 dependent upon temperature, speed, and per cent reduction.

R_2, H, and h in inches.

V_1 = velocity of bloom entering pass in ft. per second.

V_2 = velocity of bloom leaving pass in ft. per second.

V_t = tangential or periphery velocity of roll in ft. per second.

$V_t = V_2$ in all cases unless special mentioned or being different.

$F_1 = 2.3\ A_2\ S \log_{10} \frac{H}{h} = 2.3\ A_2\ S \log_{10} \frac{100}{100-c}$ (derivation shown under Elongation).

$A_2 = bh$ = area of leaving bloom in square inches.

b = width of bloom in inches.

$F_2 = .0015$ CMS (derivation shown under Abrasion work).

$F_3 = m \frac{dv}{dt} = m \frac{V_2 - V_1}{dt} = .104\ A_2 V_2^2 (1 - \cos\theta)$ (derivation shown under Acceleration work).

$C = \frac{H-h}{H} 100 =$ % reduction when omitting spreading.

$C = \frac{A_1 - A_2}{A_1} 100 =$ % reduction when considering spreading.

A_1 and A_2 initial respectively final sectional area in sq. in.

$F_4 = Sf \frac{yM_1}{R_2}$ = collar friction resistance.

S = tensile stress in lbs. per sq. in. for steel or other metal at rolling temperature.

f = coefficient of friction between hot steel and roll collar.

f varies between .1 and .4 depending upon temperature speed and per-cent reduction.

R_2 = roll radius in inches.

- ROLLING MILL ANALYSIS -

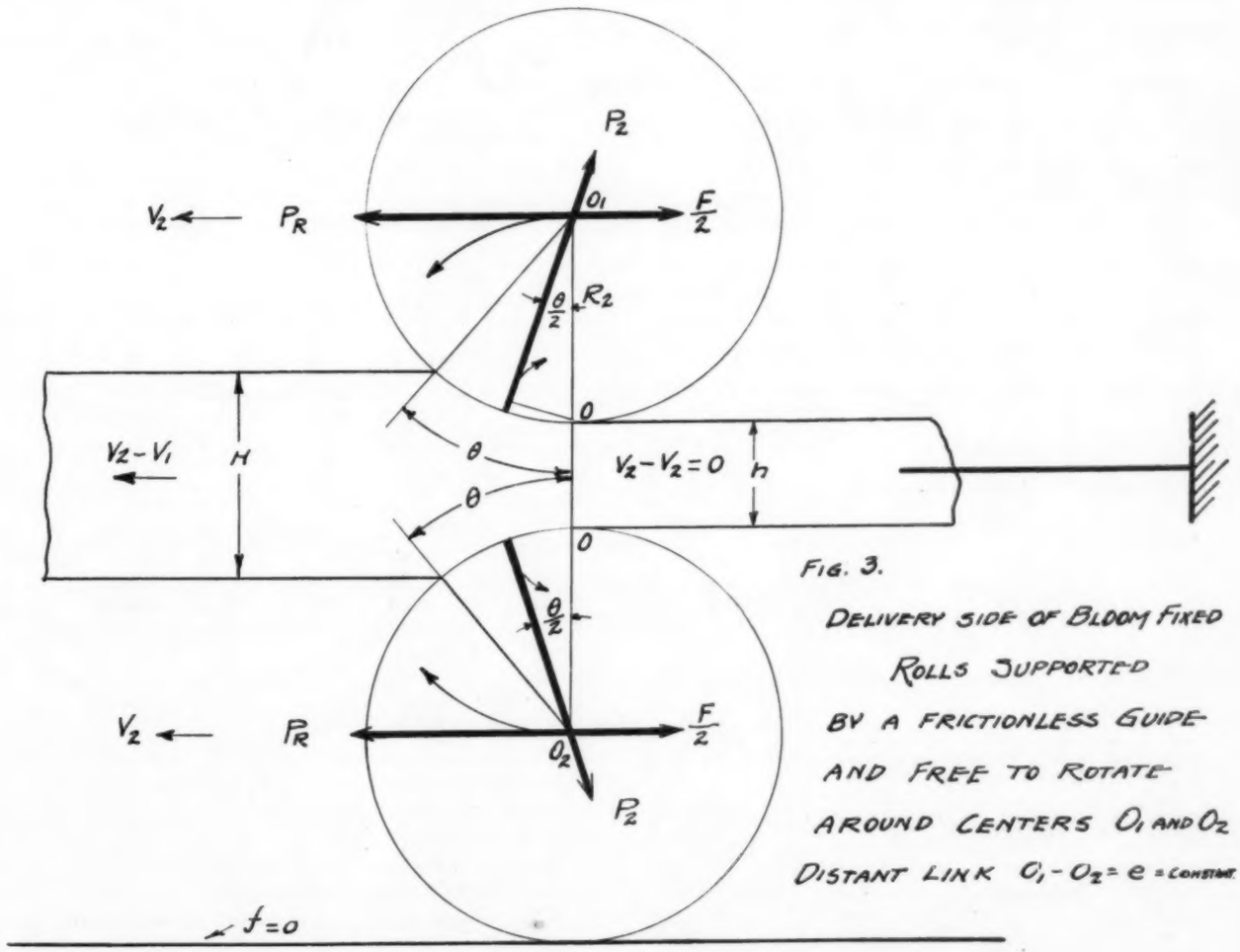


FIG. 3.

DELIVERY SIDE OF BLOOM FIXED ROLLS SUPPORTED BY A FRICTIONLESS GUIDE AND FREE TO ROTATE AROUND CENTERS O_1 AND O_2 DISTANT LINK $O_1 - O_2 = e$ = CONSTANT

y = a radius dependent upon the relative velocity and the shape of the roll collar. Discussed under roll collar resistance, y represents the mean radius of rotation in inches, when the points "O" (fig. 2 and fig. 3) are used as instantaneous centers of rotation.

M = area of contact between rolls and horizontal bloom surface per pass in sq. in.

$MS = 2\,P_2$

M_1 = the total area of contact between all the roll collars and the bloom per pass in sq. in.

The roll neck resistance is given by

$$F_5 = \frac{R_3}{R_2} f_1\, MS = \tfrac{2}{3} \times .09\, MS = \frac{6\,MS}{100} \text{ lbs.}$$

R_3 = neck radius.

.09 = coefficient of friction for brass babbit bearings subject to mill service (fair lubrication).

MOMENT BALANCE DIAGRAM

Driving Moment=Resistance Moment

$$\text{Torque per roll} = P_r R_2 = P_2 R_2 \sin \frac{\theta}{2} + \frac{F}{2} R_2 =$$

resistance torque.

$$\text{Hence } P_r = P_2 \sin \frac{\theta}{2} + \frac{F}{2}$$

$$2P_r = 2P_2 \sin \frac{\theta}{2} + F = 2P_2 f_x \cos \frac{\theta}{2} \text{ (Fig. 2)}$$

$$\text{Hence } f_x = \tan \frac{\theta}{2} + \frac{F}{2P_2 \cos \frac{\theta}{2}}$$

O = instantaneous center of rotation of each roll.

V_2 = horizontal velocity of O_1 and O_2, this assumption produces the same results as when the rolls are stationary and has the advantage of being able to show that the moments are in balance.

From the relation area x velocity = a constant follows $HV_1 = hV_2$ and $(V_2 - V_1)$ = the difference in speed of the unfinished and finished side of the bloom, i.e. the same as in Fig. 2 and therefore the resistance $\frac{F}{2}$ per roll is the same as before.

Torque

T_1 = pure rolling torque.

$$T_1 = 2P_2R_2 \sin \frac{\theta}{2} \text{ inch lbs.}$$

$$= 1/6\ P_2R_2 \sin \frac{\theta}{2} \text{ foot lbs.}$$

T_2 = delivery torque.

$= FR_2$ inch lbs.

$$= \frac{FR_2}{12} \text{ foot lbs.}$$

T_3 = combined rolling torque.

$$= R_2 \left(2P_2 \sin \frac{\theta}{2} + F\right) \text{ inch lbs.}$$

$$= \frac{R_2}{12} \left(2P_2 \sin \frac{\theta}{2} + F\right) \text{ foot lbs.}$$

T_4 = roll neck torque.

$$= \frac{12\,P_2R_2}{100} \text{ inch lbs.}$$

$$= \frac{P_2R_2}{100} \text{ foot lbs.}$$

$T = T_3 + T_4$ = total torque to be delivered to pass.

$$\text{H.P.} = \frac{T2\pi n}{33000}$$

n = revolutions of roll per min.

T in foot lbs.

$$\frac{33000 \times HP}{.12\,C\,A_2\,V_2} = \text{foot lbs. work per cu. in. displacement.}$$

$$C = \% \text{ reduction} = \frac{A_1 - A_2}{A_1} 100$$

A_1 and A_2 = initial and final area of section in sq. in.

V_2 = delivery velocity in feet per min.

The available space for this paper does not permit to give the complete derivation of the formulas given under the figures two and three. The complete outline on rolling mill analysis is prepared in book form intended to be published in the near future.

The application of the formulas in their simplest form is shown in following tabulation which covers four different mills.

The application of formulas pertaining to rail and structural mills requires too much space and had to be omitted, but will be discussed when reading the paper during the convention.

Relation between temperature and tensile strength of iron and steel.

1 lb. per square inch = .0703 Kilogram per sq. cm.
1 Kilogram per sq. cm. = 14.223 lbs. per sq. inch.
S=tensile strength in lbs. per sq. inch.

Temperature degr. F.	Wrought Iron	Mild Steel		Hard Steel	
	.05-.15% carbon	.30% carbon	.50% carbon	.75% carbon	1.00% carbon
2200	2250	.....	.....	.....	.....
2100	3500	4000	.....	.....	.....
2000	4500	5000	5600	6500	.....
1900	5100	5800	7300	8800	13000
1800	5800	6700	8800	11000	17000
1700	7000	8600	10700	13800	23000
1600	8600	10000	12500	15600	31000
1400	12600	14000	15500	17000	.....
1200	18000	.....	.....	.....	.....
1000	25600	.....	.....	.....	.....
cold (60)	50000	70000	85000	100000	120000

The strength of iron and steel as shown in above tabulation is taken from various data published by different authors and has given me satisfactory results in practice.

The values given for cold steel are averages reported by eminent investigators.

The knowledge of the strength of steel at different

ROLLING MILL ANALYSIS.
APPLICATIONS

Pertaining to		8" Merch. Mill	14" Merch. Mill	36" Sl. & B. Mill	160" Plate Mill
Given Data					
Main roll radius	R_2 in inches	4	7	18	21-14
Main rollneck radius	R_3 in inches	3	5	12	15-9
Speed Main roll	R.P.M. = n	600	200	40	40
Stress = S	lbs. p. sq. inch	5,500	7,500	4,500	10,000
Overall efficiency	%	85	88	80	88
Size of section entering	$b \times H \times L$,	3" x 3" x 18'	6" x 2½" x 36'	36" x 24" x 10'	150" x ½" x 20'
Draft	d	¼"	¼"	¾"	1/16"
Calculated Data					
Reduction	% = C	16⅔	20	6¼	25
Length of section leaving in feet		21.6	45	10⅔	26⅔
Delivery velocity	ft. per sec. = V_2	20.944	12.217	6.283	7.33
Delivery time	sec.	1.031	3.68	1.698	3.638
Angle of approach	for Plate mill = θ average	20°22'	15°22'	16°36'	4°56'
Area of contact between rolls and steel	= M "	8.5312	22.529	375.484	435.0
Actual direction of P_2 Angle	= $\frac{\theta}{2}$ "	10°11'	7°41'	8°18'	2°28'
Rolling Resistance F_0 $2P_2 = MS$	$= 2P_2 \sin\frac{\theta}{2}$ lbs.	8,296	22,591	243,922	187,224
Elongation $A_1 = b''(H-2d)$	$F_1 = 2.3A_2 S \log\frac{100}{100-c}$ lbs.	7,513	20,060	234,990	161,641
Abrasion "	$F_2 = .0015 C_2 P_2$ lbs.	1,173	5,069	42,242	163,125
Acceleration "	$F_3 = .104 A_2 V_2^2 (1-\cos\theta)$ lbs.	21	7	139	1
Rollneck "	$F_5 = .09 \times 2P_2 \frac{R_3}{R_2}$ lbs.	3,167	10,862	101,381	279,643
Pure Rolling Torque	T_1 ft. lbs. $= \frac{F_0 R_2}{12}$	2,765	13,178	365,883	327,642
Delivery "	T_2 ft. lbs. $= \frac{F R_2}{12}$ $F = F_1 + F_2 + F_3$	2,903	14,663	416,056	568,342
Combined "	$T_1 + T_2 = T_3$ ft. lbs.	5,668	27,841	781,939	895,984
Rollneck friction "	T_4 ft. lbs. $= \frac{F_5 R_3}{12}$	1,056	6,336	152,071	489,375
Total delivery "	$T_3 + T_4 = T$ ft. lbs.	6,724	34,177	934,010	1,385,359
Power delivered at rolls	$\frac{T 2\pi n}{33000}$ HP	768	1,301.5	7,113	10,551
Ft. lbs. work per cub. inch displacement	$\frac{33000 \text{ HP}}{7.2 C A_2 V_2}$ ft. lbs.	1,341.5	2,034.5	1,025	4,691
Necessary coeff. of friction	$f_x = \tan A$	.36817	.28502	.31178	.11781
The apparent direction angle	$A = \tan^{-1} f$ in degrees and fractions	20°13' = .17642	15°55' = .13890	17°19' = .15112	6°43½' = .58614
HP delivered to motor inclusive flywheel effect.	at above mentioned eff.	904	1479	8891	11990

temperature is very important in rolling mill analysis and needs much more research work in order to obtain correct data for the great variety of steels required in modern design of machinery.

It is possible to check the above data indirectly by application of the formulas pertaining to rolling Resistance, Torque and Horsepower by means of wattmeters, speed recorders, flywheel and the roll pass data determined from the speed, reduction, roll diameter and dimensions of the sections to be rolled. This leaves the tensile strength as the only unknown quantity in the formulas.

Should Colleges and Universities Create A Safety Engineering Course

By J. A. VOSS*

During the past eighteen years a great safety evolution has been taking place in almost every line of endeavor and during that time many ideas were presented and many experiments tried. The result of all these efforts was the elimination of the many unworkable theories and the retention of all practical and workable ideas, which have become so well known to safety engineers and plant executives that they have been a part of the operating program, however, in this age of further knowledge in safety

J. A. VOSS

and accident prevention work (such as this in which we live today) we can readily see the necessity of safety education through which workers are taught to avoid accident hazards and also the education of engineering revision which removes or reduces the hazards right at their source.

Engineers have helped to give man practically every comfort, luxury and convenience he enjoys today, nevertheless, their creations are not entirely beneficial, for in the United States alone they contribute in no small way to the accidental death of 90,000 persons annually. Of this number 66,000 are killed in homes, on highways and in public places, while using man's comforts, luxuries and conveniences; the remainder, 24,000, are killed in industry while making the products of the engineer's genius.

In addition to this total of 90,000 accidental deaths, approximately 3,000,000 persons in industry alone are injured each year so that they are required to lose one or more day's time.

From an economic standpoint, the accident toll in the United States imposes a burden that is costing society millions of dollars in charity and in supporting homes for orphans, cripples and old people. Industrial accidents for but one year represent a loss of 296,000,000 days of work and a net loss of $827,000,000 in wages which must be borne by the workers, their families and society in general. To the employer these accidents represent a loss of $187,000,000 in compensation and doctor bills, in addition to untold sums resulting from decreased production, increased labor turnover, lowered morale, material spoilage and property damage.

This is an enormous toll to pay for things we have come to look upon almost as necessities in life; and society, workers and employers are beginning to unite in their demand upon the trained and educated safety engineer for relief from this burden.

It is very true that noteworthy advances have been made in safety work since its inception so that the field of activities reaches out into every industry and literally every home in America. Great credit is due the pioneers of the safety movement for the remarkable results achieved, but we must now look upon safety as a higher adventure and recognize the value of teaching accident prevention work by engineering colleges and universities.

Safety and accident prevention must receive a large amount of attention by the faculties of our colleges and universities if we are to continue to carry on this great and noble work of conserving human life and limb and show further reductions in our accident records.

How often have you entered newly constructed plants with fine buildings and machinery but in looking around you found many places unprotected and improperly designed from a safety standpoint. In most cases the engineer was responsible for such conditions, and it is therefore that engineering has become an important factor in accident prevention work and it is this important factor that is gradually gaining recognition, without which maximum success in accident prevention seems to be impossible and the colleges and universities should consider this factor as a very important and real part of the engineering student's education.

The National Safety Council recently interviewed the faculties of some of the leading engineering schools and as the result of this interview they learned that a great deal of good has been accomplished by some of the colleges that are to a certain extent meeting the demands of the industrial manager by teaching the fundamentals of safety to the student and impressing on him the importance of accident prevention work and the serious consideration it is given in industry. For the most part accident prevention work is taught along with other courses. For instance, an interview with the faculty of the Pennsylvania State College revealed the fact that accident prevention work receives a large amount of attention by the faculty. Various departments of

* Central Alloy Division, Republic Steel Corp., Massillon, Ohio.

the School of Engineering and the School of Mines and Metallurgy have arranged courses of instruction so that students become thoroughly familiar with the fundamentals of safety.

In the shops, all machinery has been guarded to comply with the standard of the Pennsylvania State Department of Labor and Industry. Satisfactory safeguards for belts and pulleys have been provided everywhere. Practically all machinery is driven by individual motors, so that the problem of safeguarding transmission machinery has been relatively simple.

Part of the course of machine design includes the design of safeguards for hazardous parts, such as belts, pulleys and gears. Students working in machine shops spend the major portion of their time in tool making, and the work laid out for them includes the design of tools which will provide maximum safety for the machine operators using them. The shops are on a production basis. Instead of confining their attention to exercises, the students manufacture many appliances which are sold commercially.

In the course in factory layout and design, the questions of lighting and ventilation are studied with relation to safety. Considerable time is devoted to the question of fire protection and fire prevention for all kinds of plants to be certain to cover both general and special fire hazards. The College has practiced what it preaches in this course, by providing sprinkler systems as far as finances will permit, including the basements of most of the shop buildings.

In the course of personnel management, lectures on the fundamentals of safety are given. A portion of this course is conducted in the laboratory and part of the time devoted to laboratory work is spent in making safety inspections of the shops.

The extension courses of the School of Engineering have a large enrollment among executives and workmen in industrial plants throughout the state. One of these courses is in foreman training, which consists of eight lectures and pamphlets, one of which is on safety. It reaches the foreman in about fifty organizations each year.

When the students enter the electrical engineering laboratories the first period consists of a lecture on instructions in handling apparatus. In this lecture, particular attention is paid to safety.

In the School of Mines and Metallurgy, accident prevention work is an integral part of every course. There is hardly a day passes but what safety is not mentioned to the students in connection with the particular subject under consideration. The mining engineering students probably receive more safety instructions than students in other courses.

There are two courses in the school for mining engineering students in which safety is the major portion of the study. The course in first-aid and mine rescue work, which is given in the junior year, is a condensed course in safety engineering. The training includes mine sanitation and hygiene in addition to actual practice in first-aid administration and the use of breathing apparatus. Another course is the study of various mine laws and safety codes, and the object of it is to familiarize the student with the various state mine laws and to study all of them for the best features of each law. Mining engineers should take an active part in the formulation of these mine laws, and the study of them cannot but help to impress upon the student the necessity for safety in mines.

Each engineering student is required to work in industries during the summer to obtain additional graduation credits. In this way the students become acquainted with safety work and its application, also carry back to the college some ideas on safety that have been developed.

Accident prevention at Penn State has received more attention than has been the case at the majority of the engineering colleges. Instead of interfering with the teaching in regular efficiency courses it has added an interest in production which has been an important factor in holding the attention of the students.

The University of Pittsburgh, Carnegie Institute of Technology and the Ohio State University also impress upon their students the necessity of doing all in their power to prevent accidents. These institutions have done splendid pioneering work along this line and at this time, I want to pay tribute to the faculty of these institutions for their efforts and assistance in promulgating the safety movement in their respective institutions.

The fact that safety is already a part of the curriculum of some colleges and universities should encourage other institutions to consider this subject. I believe that all colleges and universities should consider the development and adoption of a course of safety education to include all phases of the safety movement. The day is fast approaching when safety work will be looked upon as a profession and the movement will require many more trained men—men who can visualize the vast field of accomplishment that is open to the man who will give accident prevention the consideration it deserves and men who have the knowledge and ability not only to improve production methods but also to secure production with safety, and besides this we shall produce a new generation that will have a better attitude of mind to start out with.

It is highly fitting that we in America should develop a Safety Engineering Course in our colleges and universities and while a four-year course would not be desirable and would not be in great demand either on the part of students or industries, nevertheless, it would require at least two years to teach the student all detail and ideals of sharing opportunity and responsibility for the conservation of life and limb. The detail of a course as outlined can best be developed by a committee selected from the faculty of a number of leading colleges and universities. If this committee should desire advice or guidance on this important subject I am certain that organizations specializing in Safety stand ever ready to assist them.

We are a people that are used to tackling big jobs and doing difficult things. Here is a real job—to teach the science of safety, a well defined plan of safety engineering in colleges and universities—to conquer and wipe out this national disgrace caused by accidents and bring about a much needed safety consciousness.

Gentlemen, we must awaken to this safety con-

sciousness before we can expect to cope successfully with this ever growing problem. I am confident that we are able to develop this plan and strengthen the bonds which increase human happiness by preserving and prolonging life and in doing this we shall rise to a higher type of living in every way.

Organized Inspection as an Aid to Crane Maintenance

By T. J. Flaherty*

Back in the days before Safety was considered a major problem in the operation of steel plants, the overhead electric crane was the source of a great many costly accidents and delays. Although these accidents and delays caused steel plant executives a great deal of worry, they were accepted more or less as a necessary evil, and no concentrated effort was made to eliminate them. In those days the job of following or working

T. J. FLAHERTY

under a crane was a very hazardous one due to frequent spills and dropped loads caused by broken cables. The usual cause of a broken cable was over-hoisting due to the absence of an effective limit switch.

During the past ten or fifteen years a number of improvements have been made through the co-operation of crane manufacturers, electrical equipment manufacturers, and crane users. These developments include effective limit stops, dynamic braking controllers, improved magnetic brakes, worm and ratchet gears, roller bearings, the elimination of stud bolts, the substitution of steel castings and structural steel parts for cast iron, and many others. So that today, with all the improvements that have been made through these various agencies, the safe and continuous operation of electric cranes is purely a matter of operator training and good maintenance.

A system of operator training has been in use at the plant with which I am associated for several years. Under this system if a man working in any department of the plant decides that he would like to become a crane operator, he applies for a Crane Practice Card. Before this card is issued the applicant must pass a rigid physical examination, especially with respect to eyesight and hearing. This examination must also be passed every twelve months by every crane operator in the plant. The Crane Practice Card must then be approved by the Superintendent of the department in which he is then working, by the Safety Advisor, the Electrical Superintendent, and by the Employment Department on his past record.

After securing the Crane Practice Card the prospective crane operator arranges to practice on a crane in the presence of the regular operator on his own time. This practice time is usually taken before or after the completion of the time on his regular job, so that he suffers no financial loss during the training period. This practice period covers several weeks until he has demonstrated his ability to proficiently handle a crane, and until he has mastered the rules for operating electrical cranes. A poster setting forth the Rules for Operating Electric Cranes is framed and hung in the cab of each crane. These rules are in accordance with those adopted by the Association of Iron and Steel Electrical Engineers with adaptions to suit our particular conditions. The new operator is then given occasional turns on various cranes until a regular crane operating job can be found for him.

This training practice must be followed by all applicants for crane operating jobs who are employed at the time in some other department, regardless of whether they have had previous experience or not. In the relatively rare cases when a man with previous experience is hired especially for operating a crane, he is put on the crane with the regular operator for about a week until he is thoroughly familiar with ground conditions for that particular crane.

About a year ago we inaugurated a system of crane inspection which we feel has been of material assistance to us in keeping our cranes in a high state of maintenance. This system provides for a monthly inspection of every crane in the plant by a committee of three electrical inspectors who may be accompanied in special cases by a member of the Maintenance Engineering Department and the Safety Department. These inspectors are selected by the Electrical Superintendent from the regular Motor Inspectors working in various departments of the plant. Care is exercised to select men who are thoroughly familiar with every phase of crane operation and maintenance. Each inspector serves

* Electrical Supt., American Rolling Mills Co., Ashland, Kentucky.

on the committee for a period of three months, one new man being added each month. The man serving for the third successive month acts as chairman of the committee. This inspection is, of course, in addition to the routine daily inspection made in the various sections.

This monthly inspection covers all of the following points:

(1) General conditions and appearance with respect to cleanliness and orderliness.
(2) Loose bars, boards, tools, or other objects which might fall and cause an accident.
(3) Safety devices, including fire extinguishers, safety signs, guards, railings, track brushes, gongs and sirens.
(4) Mechanical parts, including gears, shafting, girders, end trucks, hoist drums, cables, and foot brakes.
(5) Electrical equipment, including motors, controls, wiring, magnetic brakes, lights, collector bars and collector shoes.
(6) Rails on crane runway, including bolts, clips, and angle bars.

After each inspection the committee prepares a typewritten report showing the condition of each crane. From this report each crane is given a percentage rating on a purely arbitrary basis. The method of rating has been standardized in so far as each defect found by the committee counts five per cent against the crane. A crane with no defects is rated at 100 per cent. Such items as loose bolts, loose material on crane walkways, missing safety flags, empty or misplaced fire extinguishers, excessively worn bearings and gears, loose gear guards, broken rivets, bad wiring, and dirty conditions on all cranes are considered as defects.

Under our scheme of organization the Electrical Maintenance Department is divided up into a number of sections. Each of these sections is in charge of an Electrical Foreman who is responsible for the maintenance and operation of the cranes in his respective section. From the ratings of the individual cranes an average rating of the cranes in each section is determined. A plant average is also determined each month by taking the average of the ratings of the total number of cranes.

The average rating for each section is shown in tabulated form in the order of the percentage rating, from the highest to the lowest. These ratings are compared from month to month and each foreman strives to improve his position in the Table of Foreman's Standing. Copies of the Inspection Committee's Report together with the Table of Foreman's Standing are sent to each foreman monthly. The Management and the Safety Department also receive copies of these reports. In this way the foreman is shown the defects found on each of his cranes, and it gives him an opportunity to correct them before the next monthly inspection.

The results obtained under this system of inspection have been very gratifying and we feel that it is well worth the time and effort expended. The first inspection made in May, 1929, showed a plant average of 75.5 per cent, and subsequent inspections have shown a gradual rise until the inspection made in January, 1930 showed a plant average of 92.1 per cent. Under our system of rating, we feel that if we can maintain a plant average of around 85 per cent, we are applying a very high standard of maintenance to our cranes.

The Foreman's Standing for the Month of January, 1930, was as shown below:

Foreman.	January.	December.	Pos. last month.
F. M. Gross	100%	100%	1
C. Y. Stull	96%	98%	2
J. E. Funderburg	93%	89%	5
Wm. Trimble	92%	92%	3
R. W. Slagle	89%	92%	4
A. J. Hopes	88%	77%	7
B. E. Kirk	87%	82%	6

Plant average for January—92.1%
Plant average for December—90.0%

The following is a typical Crane Inspection Committee report:

From: Crane Inspection Committee.
To: Mr. T. J. Flaherty, Electrical Supt.
Subject: Inspection of Cranes.

Crane #35: O. K.

Crane #10:

Loose bolt in bearing cap on main bridge line shaft. Loose bolt in second bearing cap on line shaft. Cotter key out of pin in brake shaft. Loose bolt in end truck on upper river side main trolley. Loose bolt in back axle bearing cap on river side of main trolley. Loose material on main trolley. Loose bolt in oil cellar on lower river side. Gear guard loose and bent on aux. hoist and dragging on trolley runway. Loose base bolt in main trolley motor. Bolt loose in brake shackel on main hoist. Crane dirty.

Crane #1:

Bolt out of gear guard on bridge motor on lower river side. Bolts loose in lower hill side oil cellar. Fish plates loose on main trolley runway on down river side. Bolt out of limit switch base on aux. trolley. Bolt out of aux. hoist cross member and three bolts loose. Bolt out of rail clamp on aux. trolley runway on down river side. Two base bolts loose in upper main hoist motor. Crane clean.

Crane #2:

Bolt loose in trolley jack shaft bearing cap. Bolt loose and one out in gusset plate on upper river girder. Crane clean.

Crane #33:

Bolt loose on upper river gusset plate on girder and one out in lower hill gusset plate. Crane extra clean.

Crane #5:

Bolts loose in main hoist jack shaft bearing caps on upper river side. Crane clean.

Crane #44: O. K.

Crane #45: O. K.

Crane #46:

Base bolt loose in trolley motor. Crane clean.

Crane #47:

Bearing cap loose on jack shaft. Crane fairly clean.

Crane #43: O. K.

Crane #9:

Angle iron broken loose from down river girder which supports cab. Bridge motor badly oil soaked. Bolt out of cab support on lower hill end. Clean.

Crane #8:

Bolt loose in down river oil cellar. Bottom half of main jack shaft gear guard off. Gear throwing oil and gearshield over girder. Crane clean.

The above mentioned angle iron projecting out over ladder to No. 8 crane has never been changed. This angle has been reported several times.

Crane #11:

Guard loose on peel motor. Cellar bolt loose on upper hill side. Main switch in cab in bad condition. Crane fairly clean.

Crane #3:

Loose base bolt in peel motor. Crane fairly clean.

Crane #6: O. K.

Crane #7:

Bolt out of gear guard on main line shaft. Base bolt loose in bridge motor. Loose oil pan straps hanging on upper hill end. Crane clean.

Crane #17:

Loose rivets in hill end girder, top support. Loose rivets in gusset plate on hill end. Rivets loose on down river end gusset plate. Bolt loose in same place. Crane fairly clean.

Crane #18:

This crane has no bell or safety flag on it. Bolt loose in lower hill end bumper. Trolley jack shaft has not any top gear guard. Crane fairly clean.

Crane #21: O. K.

Crane #16:

Loose case bolt in main hoist motor, pinion end. Main hoist limit switch has no washer nor cotter pin in weight. Gear guard broken and loose on bridge drive shaft on river end. Crane fairly clean.

Crane #37:

Bolts loose in A frame on tongs. Crane clean.

Crane #34: O. K.

Crane #19:

Loose fire extinguisher laying in cab; not mounted. Loose case bolt in trolley jack shaft. Loose case bolt in trolley motor. Gear guard dragging on trolley drive and dragging on girder. Loose bolt in bearing cap on main line shaft. Crane oil soaked.

Crane #38:

This crane has not any safety flag. Base bolt loose in hoist motor. Bolt loose in hoist jack shaft bearing cap. Crane clean.

Crane #20:

Trolley drive gear guard dragging on girder. Case bolts loose in hoist motor. Bolt loose in back axle bearing cap. Rail clamps loose and one gone. Loose material left on crane. Crane very oily.

Crane #24:

Bolt loose in back axle bearing cap. Crane clean.

Crane #23:

Cellar bolt loose on lower river end and one loose in upper river end. Crane clean.

Crane #42: O. K. Extra Clean.

Crane #25: O. K.

Crane #26:

Oil cellar bolt loose in trolley on lower river side. Safety brushes are off river side at present time but are to be replaced when bumpers are put on. (Information from B. E. Kirk.)

Crane #29:

Bolts loose in stop lock. Case bolt loose in transfer motor. Loose bolt in transfer track. Loose base bolt in bridge motor. Crane has not any safety flag. No bell nor horn. Crane clean.

Monorail Crane #52:

King bolt loose on hill end. Crane dirty.

Crane #30:

This crane has no safety flag. Bell out of commission. Loose bolt in end truck on lower hill end. Crane clean.

Crane #56:

Bolts loose in main collector staff. No gear guards on main line shaft gears. Bolt out of safety shield on upper hill end. Bolt out of safety brush support on lower hill end. Crane clean.

Crane #51:

Bolt loose in limit switch trip arm. Crane clean.

Crane #31:

Base bolt loose in limit switch. Bolt loose in base bridge line shaft. Base bolt loose in bridge motor. Crane clean.

Crane #49:

Bolt out of conduit clamp on light circuit. Flexible conduit in bad order on lights on upper hill end. Crane clean.

Crane #50:

Field pole bolt loose in bridge motor. Base bolt loose in hoist motor. Bolts loose in collector rails. Crane clean.

Crane #36:

Base bolts loose in hoist motor. Lock nut loose on cellar bolt that holds main drive shaft gear guard on upper river side. Crane clean.

Crane #32:

Loose case bolt in trolley motor. Crane clean.

Crane #28:

Loose base bolt in hoist motor. Crane clean.

Crane #58:

Base bolts loose in trolley motor. Bolt loose in trolley jack shaft bearing cap. Crane clean.

Crane #27:

Base bolts loose in hoist motor. Crane clean.

Crane #48: O. K.

Crane #39: O. K.

Crane #41: O. K.

Crane #40: O. K.

Crane #15:

No safety brushes on main bridge wheels. Crane clean.

Crane #57: O. K.

Crane #14:

Bolt loose in brake shaft support. Loose bolt in bearing cap on main line shaft. Loose base bolt in hoist motor. Loose bolt in bearing cap in aux. drum on lower river side. Crane dirty.

Crane #54: O. K.

Crane #55: O. K.

Crane #12:

Trolley cellar bolt loose on lower hill end. Bolt loose in bumper on lower river end. Crane clean.

Crane #22: O. K.

Respectfully,
Crane Inspection Committee.

Yearly Review of Electrical Developments Iron and Steel Industry 1929-1930

By W. H. BURR*

The year 1929 will be remembered by many on account of the Stock Market fluctuations. Others, however, will remember it as a year in which engineering achievements exceeded any previous year in history. The World Engineering Conference and the World Power Conference have placed engineering on a firm international basis which will result in even greater engineering achievements.

W. H. BURR

The Electrical Industry paused during the past year to pay tribute to the men who laid the foundation of the Industry and made possible the things which today are necessities but were luxuries 25 years ago. Let us, therefore, pause for a brief period and consider some of the changes which have taken place in the Electrification of Steel Mills during the past 25 years.

Probably the first application of electricity in the Iron and Steel Industry was made for lighting in 1882, but it was not until 1891 that the first direct current generator was installed for power purposes in steel mills in United States. In 1892 modified railway type motors were installed on Steel Mill cranes. These motors were looked upon as a means of supplying power at points where steam was not available, but in a short time they proved to be more reliable and vastly more economical than existing steam drives.

It was about 25 years ago that the first steel plant was designed and constructed with the view of using electrical drives wherever possible. While railway type motors had been used in Steel Mills for certain classes of comparatively light machinery, it was a very different problem to drive the screw down and reversing tables electrically on account of the sudden and frequent starting and stopping, violent reversal, heavy overloads, and rough handling of the motors.

*Chairman, A.I.&S.E.E. Electrical Development Committee. Elec. Engineer, Lukens Steel Co., Coatesville, Pa.

It was at this time that the so-called Mill type motor was brought out by manufacturers of electrical equipment. Previous to this time, some pioneer work on automatic control had been done in connection with the electric elevators and hoists. To meet these new applications in Steel Mills, automatic controllers of the solenoid type were developed and many present can still hear the mill whistle blowing for an electrician to release one of the solenoids which had stuck and was holding up the operation of the mill.

It was in 1905, 25 years ago, that the first main roll drives were installed in Steel Mills in the United States. Since that time there have been installed in the United States and Canada some 1900 main roll drives. The total HP now installed on main roll drives is over two and a quarter million HP.

A light Rail Mill, in the Edgar Thomson Works, of the Carnegie Steel Company, is reported as having the distinction of being the first rolling mill in the United States entirely equipped with electric motors. The first paper on the application of motors to main roll drives which the writer was privileged to read gave a description of this installation and was written in 1906 by B. Wiley, one of our members who has contributed in no small way to the success of this Association.

During the year 1905, the Illinois Steel Company installed two 25 cycle, 2200 volt, AC motors on Rail Mills in their South Chicago Works and the Ontario Iron and Steel Company installed similar motors on existing Merchant Mills.

The application of motors to reversing mill drives was given consideration by some European Electrical Manufacturing Companies previous to 1905. One of the most serious problems encountered was the capacity of the existing generating stations which without provision for equalizing the input to the motors would not carry the load imposed. During the year 1905, it was decided to try experiments when remodeling a reversing mill at Trzynietz, Austria, and after considerable time had been spent testing the existing engine-driven mill, an order was placed for the necessary electrical equipment. It was so successful that this method of drive was given consideration wherever mills of this type were being designed or rebuilt.

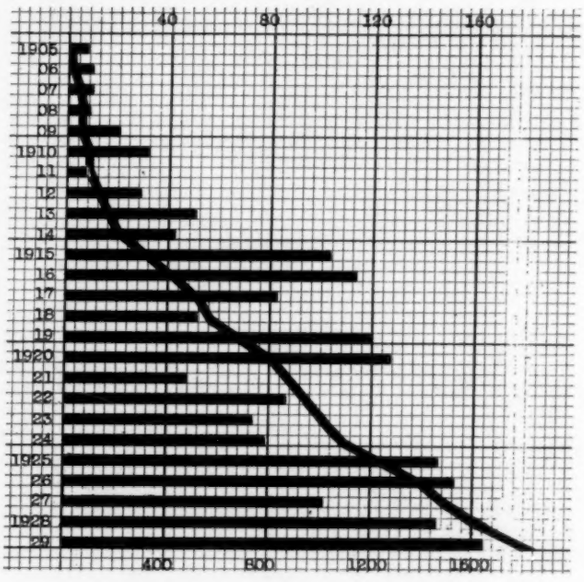
It was not until 1906 that a reversing mill of this type was designed in this country and in 1907 it was put in operation. This was a 36" Universal Plate Mill, in the Illinois Steel Company, it being the third reversing mill in the world to be electrically driven. Those who were responsible for the design of the equipment certainly exercised extraordinary engineering ability for today this type of drive is the last word for Universal Plate Mills and Blooming Mills and even on Continuous Mills. This equipment is still in service and to date there are only eight motors on Plate Mills which exceed the capacity of this drive.

Next in order of developments came the AC speed set which is now being surplanted to some extent by DC adjustable speed drives. The synchronous motor although a later entrant in the field is today receiving more consideration than other types of motors.

From this beginning in 1905, the use of motors on main roll drives has increased until during the year 1929 there was purchased 250 such drives, representing a total of 361,300 HP.

A description of the installations made during the past year together with the revised list of all main roll drive motors now in the United States and Canada will be found in the January issue of the IRON AND STEEL ENGINEER. These are now so complete that it does not seem advisable to duplicate that information in this issue. I will, however, emphasize some of the outstanding facts regarding these drives and some of the advantages gained by the use of this modern equipment.

NUMBER DRIVES INSTALLED PER YEAR



Total Number Drives Installed

FIG. 1—Graphic Chart Showing Yearly and Total Number of Drives, 300 H. P. and Over Installed on All Types of Mills.

It is of interest to note that of the 201 rolling mills built and under construction during 1929, 48 were cold sheet mills, 25 were hot sheet mills, and 26 were cold strip mills. This information, together with the fact that 15% of all steel produced last year was made into sheets, indicates the influence which the production of automobiles has on the steel industry of today.

MAIN ROLL DRIVES

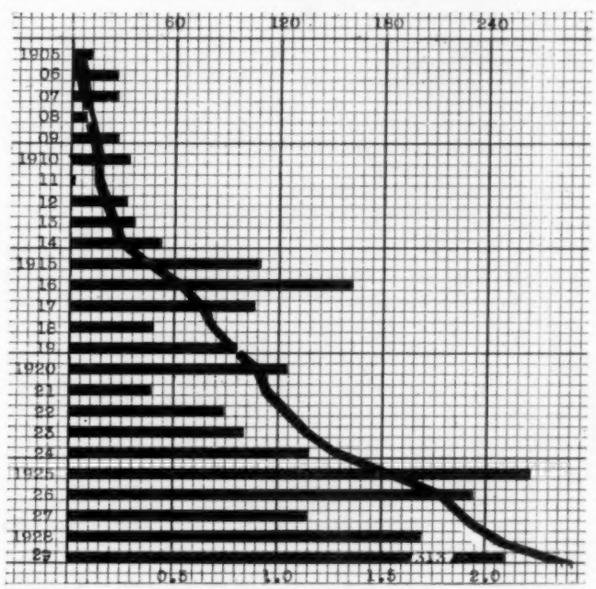
Reversing, DC

The application of large reversing mill drives continues, one of the outstanding installations during the past year is that applied to the wide flange beam mill at the South Chicago Works of the Illinois Steel Company. The upper and lower rolls of the 54" Blooming Mills are separately driven thus eliminating the customary pinion stand, and on the 52" Universal Beam Roughing Mill, the main stand will be driven by one motor and the auxiliary edging stand by a separate motor.

The development of this idea was probably an outgrowth of the idea of the individual stand drive which has been carried on for the past several years on various types of billet, strip, and skelp mills. The advantage of this type of drive is readily appreciated

inasmuch as it eliminates the pinion stand with its losses and maintenance and at the same time permits a variation in roll diameter thus eliminating matching of rolls and permitting flexibility in the mill operation. The operation of the twin motor drive is only slightly different than the single armature motor drive and pinion with parallel connected generators to a single motor. This twin motor drive on large mills, such as 54" Blooming Mill, permits a simpler mill construction as well as motor construction. This type of mill will require approximately a 10,000 or 12,000 HP motor. It is obvious that it would be a simpler construction to develop two motors driving individual rolls than it would be to develop a single motor driving the mill through pinions.

HORSEPOWER OF DRIVES INSTALLED PER YEAR
(Thousands)



Total Horsepower Installed
(Millions)

FIG. 2—Graphic Chart Showing Yearly and Total Motor H. P. Installed on All Types of Mills.

Constant Speed Motors

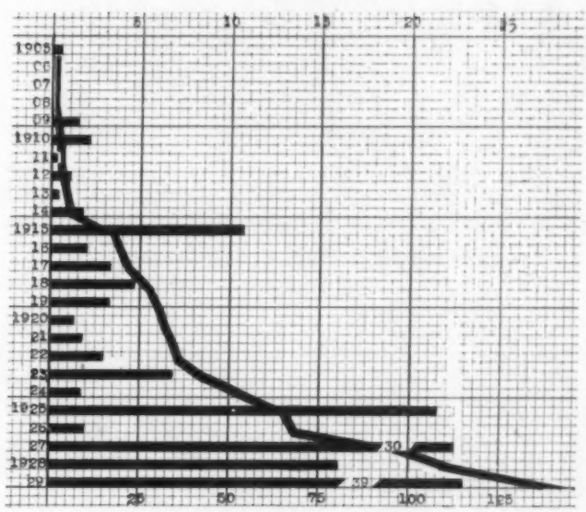
An important factor in the popularity of synchronous motors has been the improvement in the design which enables these motors to give satisfactory starting characteristics and to be subjected to full voltage during starting. As a result about 60% of the total number of constant speed motors installed during the year were synchronous motors.

This improvement in design also accounts for the fact that this type motor is now being applied to cold sheet mills. One copper manufacturing company alone has purchased ten synchronous motors to be used on main roll drives during the year. Several very large synchronous motors have been installed this year to drive motor generator sets furnishing power for DC main roll drives. With motor generator sets driven by synchronous motors, flywheels are not used, which results in a saving in cost of the set.

Synchronous motors have also been used during the past year to provide the equivalent of gearing between different stands on the same mill.

In general, experience has proven that synchronous motors are desirable in any kind of constant speed mill application where the peak load conditions are not of sufficient size to interfere with the capacity of the power plant. Existing plants generally have sufficient capacity in induction motors, motor generator sets, and other types of synchronous apparatus installed to permit the application of synchronous motors on a power system which is relatively small. The existing installation in principle acts like a flywheel and stabilizes the power so as to permit it to take heavy peak loads.

HORSEPOWER INSTALLED PER YEAR
(Thousands)



Total Horsepower Installed
(Thousands)

FIG. 3—Graphic Chart Showing Yearly and Total H. P. Installed on Tube and Piercing Mills.

Adjustable Speed Motors

For adjustable speed service, direct current motors are being used most extensively. A wide strip mill to be installed by the Illinois Steel Company, at Gary, Indiana, will be driven by 12 adjustable speed DC motors, totaling more than 20,000 HP. This installation is of especial interest for it is the first continuous wide strip mill to use DC adjustable speed motor drives on the roughing stands. Mills previously installed have had the roughing stands driven by AC motors. Power for the 12 DC motors will be supplied from three synchronous motor-generator sets, each of 4000 KW capacity at 600 volts, DC. The mill motors will be started and stopped by generator voltage control, eliminating the use of starting resistors and contactors.

Induction Motor

The old familiar induction motor drive still has certain applications where it is necessary to utilize the effect of flywheels and where minimum starting current is required. During the year an unusual installation was made where a heavier rolling schedule was desirable. To meet this condition, a second motor, a duplicate of the first, was installed and

coupled on the opposite end of the pinion shaft of the reduction gear set.

Another unusual installation is that made at the Manitoba Bridge and Iron Works, at Calgary, Alberta. Two concatenated induction motors are used to drive an 18" Merchant Mill and 10" Merchant Mill, a description of which is given in the January issue of the IRON AND STEEL ENGINEER.

AUXILIARY MOTORS

The developments in modern induction motors as compared to the earlier designs might be listed as follows: Unnecessary weight is avoided, but ample strength is provided where needed. Closed slot rotors, die cast rotors and improved brazing methods for the end rings for bar type secondaries all result in improved performance and lower costs to the user. Modern motors use (directed) ventilation and better balanced designs. Radical improvements have also been made in the bearings of these motors.

The rolled steel frame of the modern DC design gives greater strength with less weight and more uniform magnetic structure. The brackets are arranged for flat tight covers when desired and the welded foot construction is coming into general use.

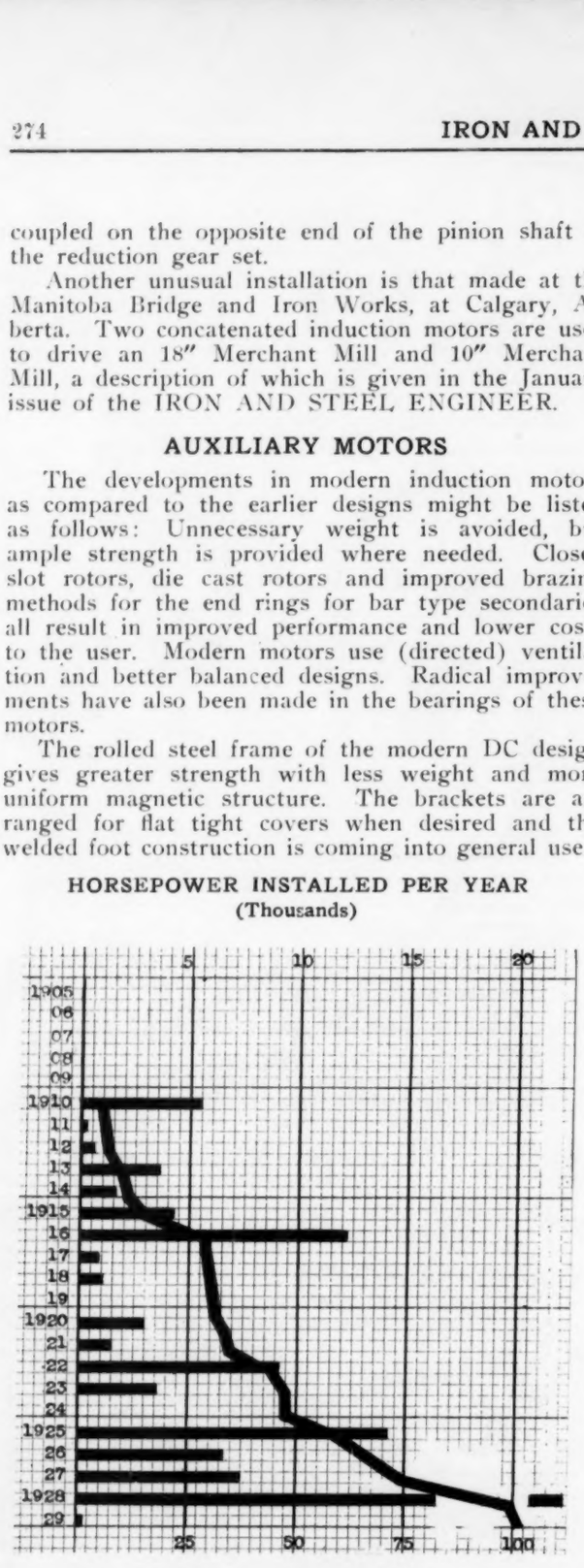


FIG. 4—Graphic Chart Showing Yearly and Total Motor H. P. Installed on Rod Mills.

The fabrication of machinery by electric welding of rolled steel sections, by which were produced the largest alternating-current units last year, this year extended to the largest direct-current equipment.

It is not merely for spectacular giants that welding and fabricating have been adopted—this year the new method of construction first became standard for all sorts of direct-current machinery—generators, motors and converters built without castings, save for bearing pedestals and die cast brushholders.

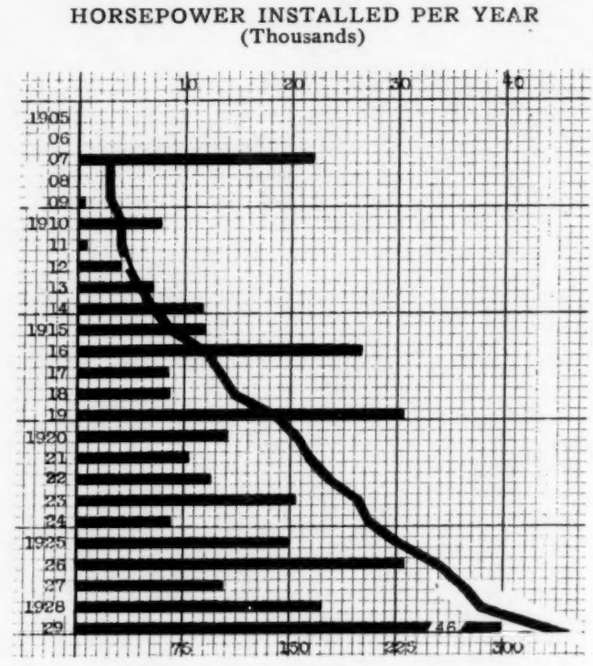


FIG. 5—Graphic Chart Showing Yearly and Total H. P. Installed on Bar and Billet Mills.

A most interesting by-product of the change to fabricated construction is the opportunity for simplifying designs into a few standard parts, from

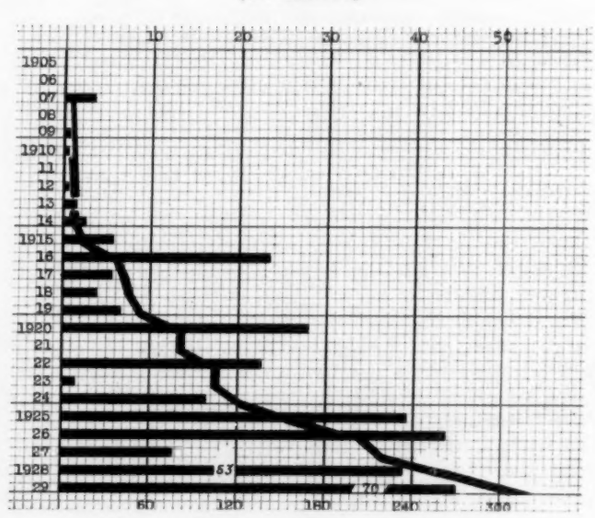


FIG. 6—Graphic Chart Showing Yearly and Total H. P. Installed on Strip Mills.

which many different machines may be made. One manufacturer states that 30 widths and thicknesses of slab makes 80 different diameters and widths of

frame, and these 80 variants replace more than 500 former cast frame designs! Three different sections of steel produce the brushholder brackets used for all sizes, replacing some 200 or more patterns of castings. Machines of every size are assembled of parts made from a comparatively few standard drawings, only the windings are separately laid out. One entire line of machines, from 300 to 8000 HP in voltage from 250 to 1500, uses but four sizes of brushes.

The upshot of all this is, of course, ability to produce machines closely adapted to the need of the user, with minimum delay, and without a burden of economic waste.

Advance in one branch of engineering often affects another field, seemingly unrelated. Thus high steam pressures in generating stations have produced a new species of induction motors, powerful, very fast, and hence amazingly small in size. Steam at 1200 to 1500 lbs. pressure means boiler feed pumps for equal pressures; and turbine pump design for such pressures calls for high-speed drive.

Eight motors of 1250 HP for the boiler feed pumps have been put in use which are only 37 in. diameter overall. The diameter of their rotors about 15 inches, compares with an ordinary motor of 100 HP, 900 RPM. They weigh less than a third as much as an ordinary industrial motor of equal power. Their speed, 3600 RPM ,synchronous), is of course the maximum possible on 60 cycles. They drive five-stage centrifugal pumps, raising the boiler feed water for example, in two stages to 1600 lbs. pressure, if required.

The frame is of welded structural design, which in this case incidentally saved two inches of overall diameter. The squirrel-cage rotor is in two sections divided by a space in which the deep, narrow squirrel-cage bars serve as a ventilating blower. No oiling system was supplied with these motors, the oiling being cared for by a plant supply. A curious result of the speed was the vacuum in the bearings, which, had it not been for special preventive means, would have sucked out the oil.

MAGNETIC CLUTCHES

A new design known as the Duplex Magnetic Clutch has been developed. This type of clutch is for particular application to hard service.

In the Duplex design, the magnet members have no relative rotation. They are fastened together and rotate as a unit. The armature member is carried on a spring plate which is bolted at the inside to a projection from field member. The magnet members carry flanges extending outward on which are mounted the metal friction members which clamp the lining faces. Provision is made for adjusting the distance between the metal friction faces, and also for setting the lining carrier to provide positive clearance when the clutch is disengaged.

This design increases the lining area and the driving force for a given diameter, and reduces the possible damage which may result from improper maintenance. When the magnet members make contact as the lining wears, the clutch loses all driving force and obliges the maintenance crew to readjust. In that condition, the magnet members cannot score each other since they have no rotation relative to each other.

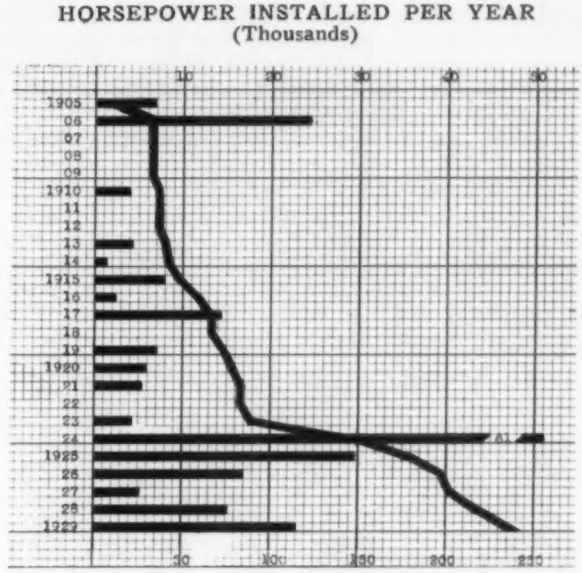


FIG. 7—Graphic Chart Showing Yearly and Total Motor H. P. Installed on Structural Mills.

CONTROL

On modern magnetic contactors, the magnetic circuit and arc box side plates are so designed that maximum efficiency in extinguishing the arc is secured. Boxes on contactors which have been in service on a 44" Blooming Mill screw down 18 months, controlling two 150 HP, type MC motors, are still in good condition. This represents more than 7,000,000 operations. A shunt from the same contactor after three years service, or after approximately 15,000,000 operations, is still in satisfactory condition. This is typical of the improved performance of magnetic control apparatus for steel mill auxiliaries.

Dynamic braking hoist controllers have hitherto been open to the objection that the release of the solenoid brake was sluggish in the lowering direction, making it necessary to pause on the first point to give the brake an opportunity to release before advancing the controller, frequent brake adjustments being necessary to prevent entire failure of the brake to release.

With new dynamic lowering circuit developed this year, the brake releases instantly. Instead of passing only one-third of the line current through the brake on the first lowering point, this new circuit passes all of the line current through the brake. The operator no longer has to hesitate on the first step, he can move his master controller instantly to any desired speed point. Improper brake adjustment has little effect on this quick release.

This improvement insures faster crane operation, more accurate control of short, quick movements of the crane hook and better ability to spot loads.

The year 1929 saw the application of an automatic screw down to plate mills, and structural mills. Development work has been done on the simplification of this device for these types of mills. The success of this type of screw down is appre-

ciated in the simplicity of operation which it permits on tandem drives, such as structural mills, requiring vertical edgers and horizontal rolls, and on the manipulation of plate mills which have a comparatively fixed schedule and fixed passes.

During the year there has been considerable development in the application of a voltage control system to screw down motors. The advantages of this scheme over the present resistance type of control are: less maintenance, ease of operation, faster manipulation of the screw down, and simplicity of control. All of these factors are of vital importance and result materially in the efficiency and the increased production of the mills.

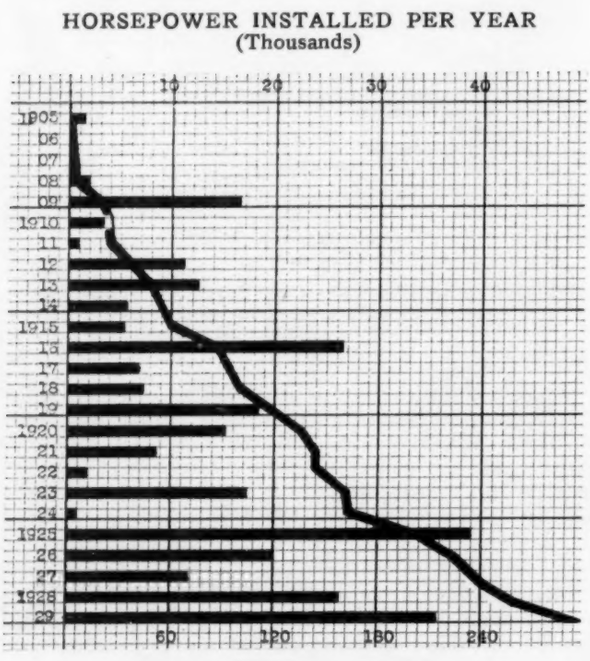


FIG. 8—Graphic Chart Showing Yearly and Total Motor H. P. Installed on Merchant Mills.

The year has also seen the development considerably accelerated for the installation of photo-electric cell for use as flag switches. In addition to the applications, the successful operation of the photo-electric cell has created other applications, such as direct and recording temperature indicators to replace the present pyrometers, counters for sheets, tubes, billets, and ingots, fire prevention, etc. The field of application for this little device is spreading rapidly and the demand for photo-electric cell in the steel mills in the next few years will be greatly increased. The design of this apparatus lends itself to practically any application where it is desired to automatize a mechanical operation or adjust an operating condition to obtain increased production.

CRANES

The most noticeable difference between the design of up-to-date cranes and those 25 years ago is in the safety features. In looking back over the specifications for cranes, about all that was required was speeds for various motions, hook travels, etc., nothing being said whatever with reference to safety features. The total specifications did not cover more than several pages, while specifications applying to cranes up-to-date in some cases cover as high as thirty to forty pages. These include all gears running in either cast steel or welded cases; all moving shafts to be totally enclosed and all moving parts to be protected against any person coming in contact with same; footwalks to be included on both sides of bridge, across both ends of trolleys, and on ladle trolleys to have footwalk to extend on all four sides; also calling for stairways leading from one part of crane to another.

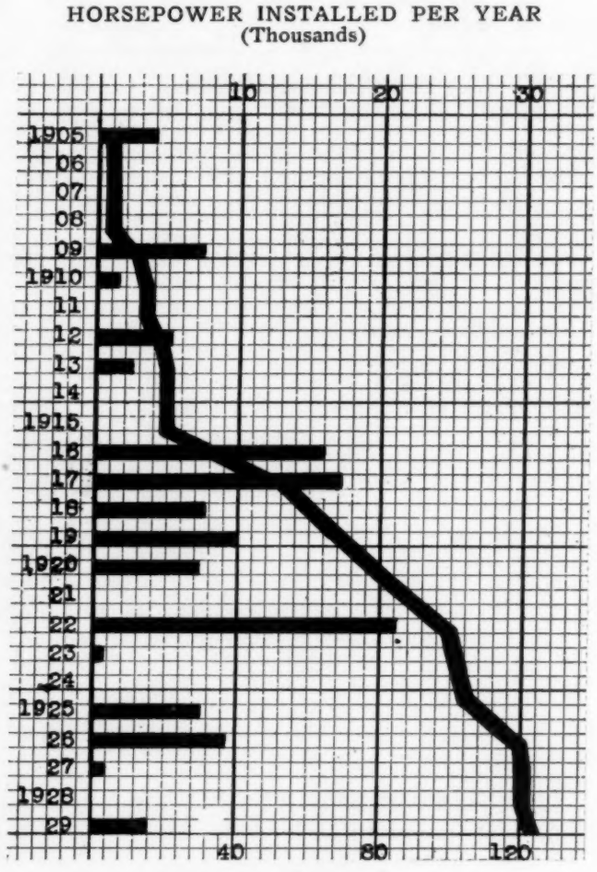


FIG. 9—Graphic Chart Showing Yearly and Total Motor H. P. Installed on Plate Mills.

Crane statistics for the year 1929 were also published in the January issue of the IRON AND STEEL ENGINEER. These statistics show that 540 cranes were built for the Iron and Steel Industry, representing an approximate value of $10,000,000. It is also very evident that the anti-friction bearing cranes are increasing in popularity. The use of worm gear reductions is becoming more general each year and heat treated gears, pinions, and track wheels are recognized as effecting a considerable saving in cost of maintenance.

A 300 Ton Crane of unusual design is now being built for Illinois Steel Company, South Works. This crane is used for handling a mill complete with its rolls in place. This crane is of the four-girder type with an Aux. trolley running on two separate sets

of girders and underneath the main trolley, similar to our four-girder type ladle crane. The main hook is supported by a heavy beam, built up of "H" sections, which is supported on either end by a set of ropes from the two interlocked drums. It might be of interest to know that the span of this 300 Ton Crane is 100' and that in order to lighten up the girders, special high grade steel is used having a tensile strength of approximately 90,000 lbs.

Cranes constructed of aluminum and its alloys have been installed during the past year and are reported as giving satisfactory operation.

REGULATORS FOR TANDEM MILL DRIVE

Regulators have been developed for speed matching control, or the driving of two or more motors at definite speeds, regardless of load and are being used on both paper machine drives and steel mill drives. The general scheme is to have the main motor drive an AC pilot generator which in turn supplies current to the synchronous motor of the sectional regulators. These regulators are adjustable by means of a variable ratio transmission and maintain all motors at the correct speed relation.

The regulator used in this service is a carbon pile type consisting of two distinct units; namely, the mechanical and the electrical unit. The mechanical unit consists of a synchronous motor, a cone pulley, and a mechanical differential. The electrical unit consists of a panel containing the control mechanism which is mounted on the mechanical unit, making the entire unit integral.

The synchronous motor supplied with this type of regulator is of the enclosed type with a squirrel cage salient pole rotor. The shaft of this motor is hollow so that an internal shaft can be connected between the cone pulley and the differential. This motor is equipped with ball bearings with provision for lubrication arranged to be very accessible. The motor end bracket which supports the differential housing has been designed in such a way as to permit the mounting of a motor in any quadrant of a circle at right angle to the axis of the shaft.

The cone pulley is mounted on the hollow shaft extension concentrically aligned by means of two ball bearings. The face of the cone pulley is pinned to the internal shaft connected to the differential clutch.

The mechanical differential enclosed and rotating in oil consists of a worm and nut, a clutch and a lever system. The worm and nut detect any angular displacement between the hollow shaft of the motor and the internal shaft of the pulley and differential and transforms this to a rotating motion through a yoke lever. The clutch is provided to allow the slipping between the shafts when the worm approaches the end of its travel. The differential housing is so designed as to allow a small angular adjustment in order to insure an upright position of the control element when the motor is mounted on the device to be controlled.

The control element consists of two carbon piles supported from a common frame, two levers acting upon the carbon piles, two dashpots and two coils with cores connected to the levers, and a differential arm which is mounted on the shaft extending from the differential housing through the panel of the control element. These various items are all mounted in a compact manner and enclosed with a sheet metal cover making the control element watertight. The differential housing and panel are so designed as to permit the panel to be mounted on either side or left hand side of the differential housing.

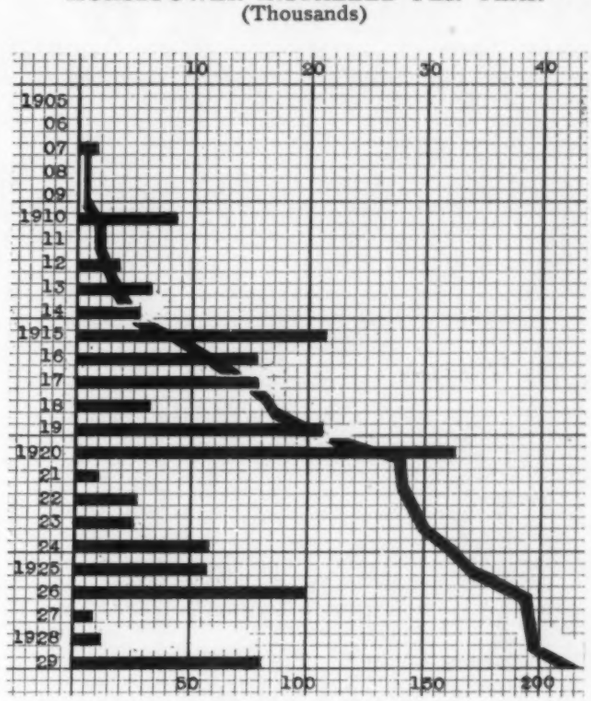


FIG. 10—Graphic Chart Showing Yearly and Total Motor H. P. Installed on Sheet and Tin Plate Mills.

During normal operation, the form and nut of the differential are in the same position between the two stop screws. The hollow shaft and the internal shaft are rotating at the same speed and in the same direction. Should the motor speed up, the cone pulley will then tend to be rotating in the opposite direction assuming an instantaneous change; that is, the relative direction of shaft rotation is opposite to each other. Therefore, the worm is forced to travel out of the nut due to the fact that the nut is held in a definite position along the axis of the hollow shaft. If the speed of the motor is not brought to synchronism within the travel of the worm, the worm will strike against either of the stop screws and the clutch will slip. The movement of the worm transforms the amount of slip or phase displacement into a rotating motion of the shaft connected to the control element lever system which in turn changes the field excitation to correct the error in speed.

METERS

Probably the biggest advance in instrument construction in the past twenty-five years has been in the use of light alloys. Many years ago when aluminum was expensive, copper was used for damping frames and for many other mechanical parts, whereas, today aluminum and its various alloys, such as

duralumin, are used throughout for the mechanical features, such as shafts, damping fans, coil frames, and similar parts. High conductivity of aluminum gives materially increased efficiency when used as the damping frame in the direct current of D'Arsonval instruments.

High quality phenolic molded materials have been used in increasing quantities in the past twenty years. This eliminates the use of wood, porcelain, and hard rubber, and gives assemblies which will remain in good condition for years without being subject to atmospheric changes.

Other materials are now being used which result in increased efficiency, such as the occasional use of cobalt steel, extra fine enamelled wire, and the like. probably in a few words, one could say that the most important improvements have been along the lines of better materials.

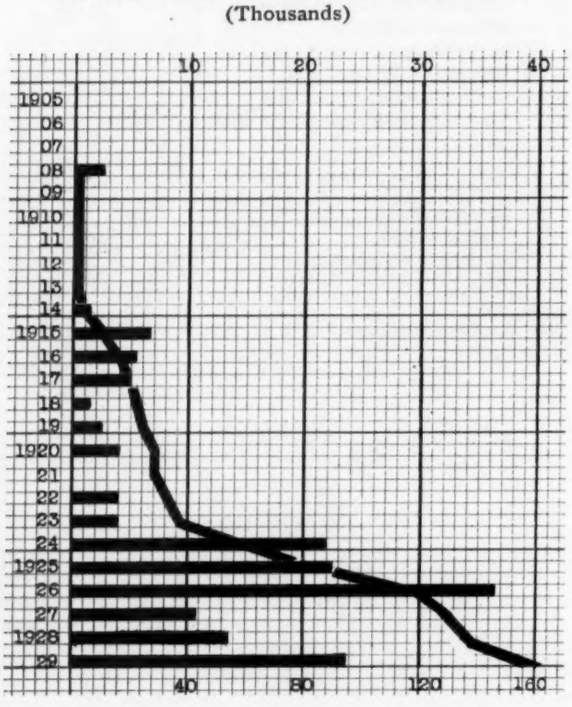


FIG. 11—Graphic Chart Showing Yearly and Total Motor H. P. Installed on Sheet, Bar and Skelp Mills.

A new frequency meter of the indicating type has been developed, the design of which permits the production of instruments having a scale range of plus or minus 2 cycles for 60 cycle work, with operating torques at least equal to those used in corresponding volt meters, and with a remarkable freedom from temperature or voltage error defects.

The ranges obtainable are from 54 to 66 cycles or from 58 to 62 cycles for use on 60 cycle systems. The narrow range scales are supplied for use on interconnected systems and applied principally to power or load dispatching.

Since such an instrument is responsive to changes of .01 cycles and frequency changes due to the load can be readily observed.

Use of a special glass which prevents glare is one of the features of a line of instruments for switchboards.

MISCELLANEOUS

Special Frequency Converters

During the past year there has been a demand for special frequency converters for obtaining frequencies different from those furnished by the power companies.

These machines are built for operation on either two-phase or three-phase current. They provide an economical method of obtaining single phase, two phase, or three-phase current at any low frequency. They are especially economical for obtaining very low frequencies such as three to fifteen cycles.

These frequency converters have been used to obtain variations in speeds with squirrel-cage induction motors and to get speeds which are either higher or lower than can be obtained from induction motors operating on a standard frequency.

Capacitators

Another development which should be of interest is the scheme that has been used for connecting a capacitator across the motor terminals during starting. This scheme was used on the two 300 HP synchronous motors for driving ball mills. The capacitator is connected to the line only during starting and this reduces the KVA inrush. After the motor has synchronized, the capacitator is disconnected from the line and is available for starting other motors.

Potheads

The first potheads were simply porcelain containers for pitch compound, with a primary function to seal the cable ends against moisture. More than twenty years ago these first potheads were combined with an air break disconnect all enclosed in porcelain.

In a little over twenty years the pothead line has grown to over 3500 styles, shapes, sizes and designs, some of which function as a seal against oil leakage from the cables.

Periodic cable improvement has generally been anticipated in the constant refinement of pothead design. A line of complete oil tight construction is an illustration.

The tendency at the present time to to build around unit parts from which standard potheads are made and special assemblies are easily available. Many companies have taken advantage of this latter convenience to get exactly what they want. The unit parts idea permits a larger stock and faster shipments.

In the present pothead design the interior is stronger than the exterior, so that line surges and etc. will flash over on the outside. These over-voltage disturbance flashovers are of short duration and seldom generate heat enough to injure the porcelain. Potheads do not take the place of arresters and choke coils. However, this safety valve feature protects the cable whose insulation could not withstand punc-

tures and continue to operate satisfactorily. This double function of the pothead has saved many cable installations.

MAIN DRIVE CHARTS

In looking over the application of motors which were made to main roll drives during the year 1929, we see that 164 main roll drives were installed, bringing the total up to 1824 motors on such drives. This is the largest number ever installed during any one year.

The total HP installed last year was 313,000 HP and in the steel industry there are now installed 2,370,000 HP on main roll drives.

The past year broke all records for reversing blooming mill drives when 54,500 HP were installed on mills of this type. This exceeded the HP installed in 1925, the highest previous to that time, by 50%. The total has now reached 275,000 HP.

Bar and Billet Mills have shown almost exactly the same percentage of increase as the Blooming Mill. In 1929 there were 45,700 HP installed on mills of this type. The highest previous year was 1926 when 31,000 HP were installed. The total capacity now installed is approximately 300,000 HP.

The year 1926 still holds the record on Sheet, Bar and Skelp Mills when there were 36,500 HP installed. Although there were only 23,500 HP installed, the year 1929 showed an appreciable increase over 1928. Total now installed is 160,000 HP.

Last year only 16,000 HP in motors were installed on Sheet and Tin Plate Mills. 1920 still holds the record for one year when 32,500 HP in motors were installed. Now the total is approximately 215,000 HP.

The demand for seamless pipe is still increasing as is indicated by the fact that during last year the HP installed on Piercing Mills exceeded that during any previous year. 39,600 HP were added last year, which brings the total up to 140,000.

23,000 HP in motors were used in driving Structural Mills last year, the total, however, is only one-third of total HP installed during 1924 which was the banner year in mills of this type. Total HP now installed 240,000.

Merchant Mills have shown a very steady increase in total HP installed each year since the very first year 1905. Last year 35,700 HP were added to Mill drives of this type making a total of 300,000 HP. This total checks very closely with the total HP installed on Bar and Billet Mills.

During 1929, 4000 HP in motors were installed on Plate Mill Drives, and there are now over 120,000 HP in service on mills of this type.

During the year 1928, 28,000 HP in motors were installed on Rod Mills and this last year only 1200 HP in motors were used for this purpose. In other words, there was less expansion in this line than any other during 1929. The total HP has reached 100,000.

Last year the total HP installed on Strip Mills was the largest ever installed on any type of mill in one year. This total for the year reached 70,000

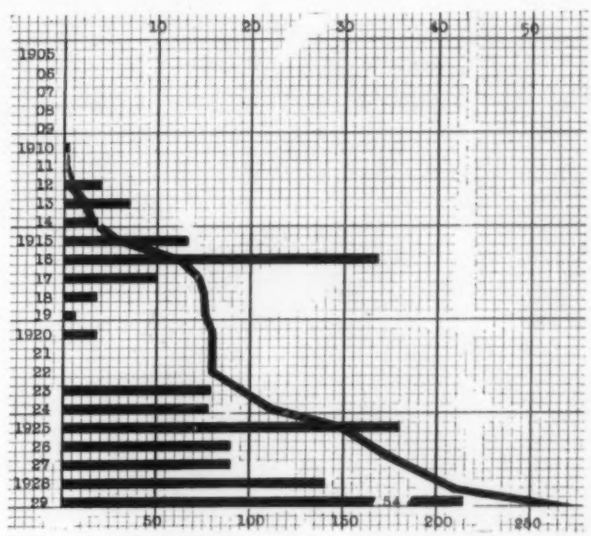


FIG. 12—Graphic Chart Showing Yearly and Total Motor H. P. on Reversing Blooming Mills.

HP, making a total of 325,000 HP now installed on Strip Mills. It is evident that the total HP installed on Strip Mills is greater than on any other type mill at the present time.

CONCLUSION

The phenomenal increase in the use of electricity in steel mills during the past twenty-five years has no doubt been one of the greatest factors contributing to the wonderful progress made by the Steel Industry. This increase in the use of electricity is a direct result of the research policy established by manufacturers of electrical equipment. Twenty-five years ago, there was in the minds of some a question as to the advisability of adopting a policy of purely research work, but today, no industry can build for the future without establishing a definite research policy.

In compiling a report of this nature, considerable effort is put forth by the individual members of the Electrical Development Committee and as chairman, I wish to thank all those who have in any way contributed to this report for their hearty cooperation and support.

Report of the A. I. & S. E. E. Special Committee on Bearings

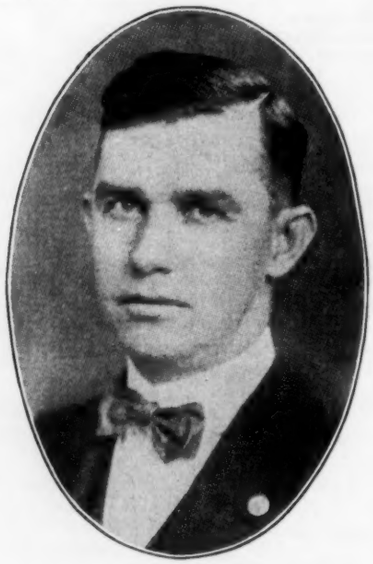
By F. D. EGAN*

Part I —Application of Anti-Friction Bearings to Mill Type Motors. Refer to June, 1929, Issue of the Iron & Steel Engineer.

Part II —Application of Anti-Friction Bearings to General Purpose Motors.

Part III—Application of Anti-Friction Bearings to Electric Overhead Traveling Cranes.

Part IV—Application of Anti-Friction Bearings to Mill Roll Necks.



F. D. EGAN

The Special Committee on Bearings of the Association of Iron and Steel Electrical Engineers present herewith their Annual Report covering Anti-Friction Bearings for use on Mill Type Motors, General Purpose Motors, and Electric Overhead Traveling Cranes.

During the year 1928 the Committee functioned with a personnel including representatives of the Mill Motor and Anti-Friction Bearing Manufacturers with the result that data was collected and tabulated in a form which represented the Motor Manufacturer's practice in design of mountings, size of bearings, tolerance of fits, etc., as well as actual physical dimensions of Anti-Friction bearings applied to Crocker Wheeler Co., General Electric Co. and Westinghouse Electric and Mfg. Company's mill type motor frames. This tabulation of data, consisting of sheets A-1, A-2, A-3, A-4, B and B-1, were endorsed by the Anti-Friction Bearing Manufacturer's representatives as their recommendation in application of their own particular bearing in each frame. It was pointed out that the committee would not submit any recommendation as to standardization in Bearing sizes and that the tabulation was a representation of existing practice in the application of Anti-Friction Bearings to Mill Motors.

Part I of the report was presented at the 1929 Convention of the Association of Iron & Steel Electrical Engineers held in Pittsburgh, Pa., and was published in the June, 1929, issue of the Iron & Steel Engineer.

Since publishing the data on mill type motors, the bearing and motor manufacturers have requested some changes be made in the tabulation to include corrections or additions which they have wished to make. The data sheets, A-1, A-2, A-3, A-4, B and B-1, have therefore been revised to include all corrections that have been endorsed by the motor builders and these sheets are again published in the Iron & Steel Engineer superseding previous publication in the records.

In addition to the corrections which have been made to the Mill Type Motor Bearing data, it develops that some Ball Bearing Manufacturers desire to incorporate their data on the application of Double Row Ball Bearings to Mill type motors. The tabulation has not been revised to include this data inasmuch as the A. I. & S. E. E. has recommended the 300 series roller bearing for mill type motors. To incorporate Ball Bearing data in the tabulation at this time would in fairness necessitate reopening the issue to the entire field of Ball Bearing Manufacturers in order to collect and tabulate all information available on application of this type of Bearing to Mill motors. There is not sufficient time to accomplish this development before data will be published and this subject will, therefore, be left for future development and investigation of the Committee.

Part II—Application of Anti-Friction Bearings to General Purpose Motors

Continuing the plan of procedure as originally outlined, the Special Committee on Bearings has functioned during the past year with a personnel including representatives of the General Purpose Motor and Anti-Friction Bearing Manufacturers as well

* Chairman, A.I.&S.E.E. Special Committee on Bearings.

as Electric Overhead Traveling Crane Builders. Data has been collected and tabulated, Sheets C-1 to C-18 inclusive, which incorporate the General Purpose Motor Manufacturers' practice in application of Ball or Roller Bearings to A.C. and D.C. General Purpose Motors. In this tabulation, data has not been included on miscellaneous commercial fractional horsepower motor frames inasmuch as their application in steel mill service is not extensive.

Referring to tables C-1 to C-18, it will be noted in general, that the motor manufacturers have carried out the practice of utilizing the S.A.E. 300 series bearing where Ball Bearings are applied. These bearings are interchangeable in mounting dimensions with the various standard Ball Bearing makes. In some instances, Roller Bearings are applied which are interchangeable in mounting dimensions with the 300 series Ball Bearing and in some instances, Roller Bearings are applied which are not interchangeable in mounting with the S.A.E. Ball Bearing sizes and tabulation is so noted where this occurs.

Bearing data is tabulated for constant speed D.C. Motor frames and 25 and 60 cycle A. C. Motor frames, together with Manufacturer's rating in Horsepower, torque and speed for each frame. No attempt is made to tabulate the complete list of adjustable speed motor ratings inasmuch as several ratings are built in one frame, all utilizing the same S.A.E. bearing size.

Part III—Application of Anti-Friction Bearings to Electric Overhead Traveling Cranes

Bearing data tabulation sheets D-1 to D-5 inclusive, incorporate Anti-Friction Bearing Manufacturer and Crane Builders practice in application of Anti-Friction bearings to Electric Overhead Traveling Crane trackwheel journals. Data is tabulated on basis of maximum load per wheel with bearings assumed to be symmetrically spaced from center line of wheel for equal bearing loads.

Bearing sizes in this tabulation are made sufficiently large to suit wheel axles of ordinary steel forging stock, .30 to .40 carbon, with ultimate tensile strength of 74,000 lbs. per square inch. The diameter of the axle at the bearing fit is computed to allow a factor of safety of not less than 5 including bending stresses. In many cases, it is possible to apply a smaller size bearing based on catalogue rating of the bearing to suit a given wheel load but this application necessitates the introduction of special alloy steel axles to obtain sufficient strength in wheel pin. This practice is to be discouraged from a standpoint of maintenance in steel mills where it is desirable to furnish renewal axles through the plants local repair shops which are not in position to furnish the special alloy steels conveniently in many cases.

Illustrations at top of each Crane Manufacturers' Bearing data sheets provide A-B-C reference sketch for bearing dimensions in the tabulation as well as indicate typical mounting styles for each manufacturers bearing indicated. Referring to table D-2, it will be noted that illustrations show a different manufacturer's bearing on each end of the wheel axles. This does not indicate the crane builders practice in design but is indicated in this manner to show typical mountings for the various manufacturer's bearings in the space available for illustrations.

It is not the intention of the Special Committee on Bearings to confine its investigation and report to the application of Anti-Friction bearings to crane trackwheel journals alone. This phase of the application of Anti-Friction bearings on cranes was given first consideration in view of the advantages obtained in reducing rolling friction and improvement in methods of lubrication. It is the intention of the Committee, however, to continue the investigation and expand the report to include adaption of Anti-Friction bearings to other shafting on the cranes as well.

In compiling and tabulating bearing data presented in this report, credit is extended to representatives of the Anti-Friction Bearing Mfg. Companies, Mill and General Purpose Motor Mfg. Companies and Electric Overhead Traveling Crane Mfg. Companies for their assistance and co-operation in submitting data including their practice and recommendations for the application of Anti-Friction bearings to their equipment.

Part IV.

The Association of Iron & Steel Electrical Engineers through the Special Committee on Bearings was the first engineering society in America to recognize the possibilities of Anti-Friction Bearings on Roll Necks and in 1927 instituted a program for the study of the application of Anti-Friction Bearings on Roll Necks.

To date, the Association has collected considerable data and has distributed this information through the columns of the Iron and Steel Engineer. However, this problem has by no means been solved and there still remains, considerable research, tests and the experiences of those applications now in use.

It would seem that one of the first problems to be settled before any real headway is made is: How and by what method shall rolling mill pressures be determined.

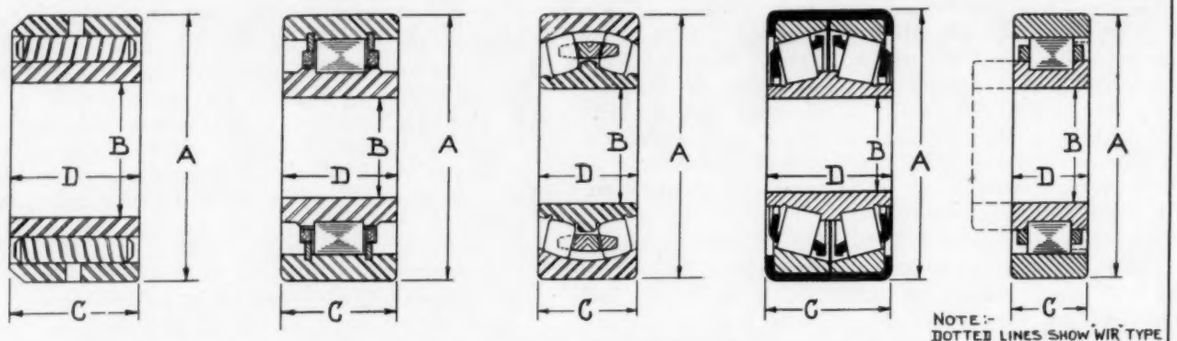
It is not reasonable to expect that some definite proceedure should be established, some formulaes advanced which will be acceptable to both the Iron and Steel Industry and the Manufacturers of Anti-Friction Bearings.

Many noted engineers both in our own United States and in the foreign countries are feverishly working on the problem of rolling pressures, two of whom have furnished interesting data so far. Professor Wilhelm Tafel who is located at the Technische Hochschule at Breslau and Dr. Ing. J. Puppe at Dusseldorf, Germany.

Our own engineers have also contributed a wealth of information on this subject.

No scientific body, no engineer, however has volunteered the information that this work is completed and that the results obtained so far, may be accepted definitely, as absolutely accurate. It may be therefore assumed that the Special Committee on Bearings has a lengthy program ahead, in its ambition to service the Iron and Steel Industry in the application of Anti-Friction Bearings to Roll Necks.

HYATT ROLLWAY S.K.F. TIMKEN NORMA HOFFMANN



MOTOR DATA						BEARING DATA										
M'F'G.	FRAME	TORQUE	H.P.	R.P.M.	MIN. PIN. DIA.	M'F'G.	SERIES	A	B	C	D	ROLLERS Nº	ROLLERS DIA	SHAFT FIT	CART'G. O.D.	FRAME BORE
						HYATT	W-209	3.3477 3.3465	1.7718 1.7711	1.562 1.555	1.5625	20	.375	.0015 TIGHT .0003 "	4.5025 4.5010	4.5000 4.4995
						ROLLWAY	MDW309	3.9370 3.9362	1.7717 1.7712	.9843	1.5625	18	.50	.0010 " .0003 "	3.375 3.377	3.3750 3.3745
						S.K.F.										
						TIMKEN										
G.E.	MD-101	22	4	975	4.00	NORMA HOFFMAN	R-345	3.937	1.7718	.984	.984	12	.50	.0010 TIGHT .0003 "	3.375 3.377	3.3750 3.3745
						HYATT	" 309	3.9383 3.9370	1.7718 1.7711	1.5625	1.5425 1.5325	14	.625	.0015 " .0003 "		3.3378 3.3373
						ROLLWAY	MS-5309	3.9370 3.9362	1.7717 1.7712	1.5625	1.5625	12	.50	.0010 " .0001 "		3.3402 3.3387
						S.K.F.	22309	3.9370 3.9362	1.7717 1.7712	1.4173	1.4173	28	.55	.0014 " .0004 "		3.3378 3.3373
						TIMKEN	8309	3.9370 3.9362	1.7717 1.7712	1.5675 1.5575	1.5675 1.5575	32	.484	.0014 TIGHT .0004" "		3.3378 3.3373
G.E.	MD402	29	5	900	3.75	NORMA HOFFMAN	R-345	3.9370 3.9364	1.7719 1.7713	.984 .982	.984 .982	12	.50	.0013 " .0002 "		3.3378 3.3373
						HYATT	" 310	4.3328 4.3306	1.9655 1.9688	1.75	1.75	14	.6875		4.002 4.000	4.003 4.000
						ROLLWAY	MS 5310	4.3307	1.9685	1.75	1.75	13	.50		"	"
						S.K.F.	52310	4.3307	1.9685	1.5748	1.75	28	.63	-.0010 -.0000	"	"
						TIMKEN	8310	4.3307 4.3299	1.9685 1.9685	1.7550 1.7550	1.7550 1.7450	28	.594	.0013 TIGHT .0003 "	"	"
W.E.M.	MC-20	44	6	700	3.50	NORMA HOFFMAN	WIR350-L	4.3307	1.9685	1.063	1.75	12	.5625		"	"
						HYATT	" 311	4.7258 4.7244	2.1656 2.1648	1.9375	1.9175 1.9075	15	.6875	.0017 TIGHT .0004 "		4.7253 4.7248
						ROLLWAY	MS-5311	4.7244 4.7236	2.1654 2.1649	1.9375	1.9375	14	.50	.0011 " .0001 "		4.7276 4.7256
						S.K.F.	22311	4.7244 4.7236	2.1654 2.1649	1.692	1.692	28	.67	.0016 " .0006 "		4.7253 4.7248
						TIMKEN	8311	4.7244 4.7236	2.1654 2.1649	1.9425 1.9325	1.9425 1.9325	32	.594	.0013 TIGHT .0003 "		4.7253 4.7248
G.E.	MD403	49	7½	800	4.25	NORMA HOFFMAN	R-355	4.7244 4.7238	2.1656 2.1650	1.142 1.140	1.142 1.140	13	.5625	.0015 TIGHT .0004 "		4.7253 4.7248
						HYATT	MW 211	3.9384 3.9369	2.3500 2.3492	1.8125	1.8125	21	.4375	.0010 " .0008 "	4.8140 4.8125	4.8125 4.8120
						ROLLWAY	MDW 312	5.1181	2.3622 2.3616	1.2205	2.125	20	.593	.0012 " .0003 "	4.002 4.000	4.0000 3.9995
						S.K.F.	22312	5.1181	2.3622	1.811	1.811			.0012 " .0003 "		4.002 4.000
						TIMKEN										
G.E.	MD 102	54	9	875	4.75	NORMA HOFFMAN	R-360	5.1181	2.3622	1.220	1.220	12	.625	.0012 TIGHT .0003 "	4.002 4.000	4.0000 3.9995
						HYATT	T-310	4.3320 4.3307	2.0008 2.0000	1.75	3	14	.6875	.0015 TIGHT .0002 "	3.939 3.938	3.940 3.938
						ROLLWAY	MDW 311	4.7244 4.7236	2.1654 2.1649	1.1417	1.9375	22	.50	.0021 " .0006 "	3.940 3.938	"
						S.K.F.	22310	4.3307	2.0005	1.575	1.575	28	.63	.0015 " .0005 "	3.938 3.936	"
						TIMKEN	8311	4.7244 4.7236	2.1654 2.1649	1.9425 1.9325	1.9425 1.9325	32	.594	.0013 TIGHT .0003 "		"
C.W.	A.W.	64	8	670	3.80	NORMA HOFFMAN	R-355-L	4.7244	2.1654	1.142	1.142	13	.5625	.0021 " .0006 "		"
						HYATT	" 311	4.7258 4.7244	2.1656 2.1648	1.9375	1.9175 1.9075	15	.6875	.0017 " .0004 "		4.7253 4.7248
						ROLLWAY	MS-5311	4.7244 4.7236	2.1654 2.1649	1.9375	1.9375	14	.50	.0011 " .0001 "		4.7276 4.7256
						S.K.F.	22311	4.7244 4.7236	2.1654 2.1649	1.692	1.692	28	.67	.0016 " .0006 "		4.7253 4.7248
						TIMKEN	8311	4.7244 4.7236	2.1654 2.1649	1.9425 1.9325	1.9425 1.9325	32	.594	.0013 TIGHT .0003 "		4.7253 4.7248
G.E.	MD404	72	10	725	4.50	NORMA HOFFMAN	R-355	4.7244 4.7238	2.1656 2.1650	1.1420 1.1400	1.1420 1.1400	13	.5625	.0015 " .0004 "		4.7253 4.7248
						HYATT	TW-213	4.7260 4.7243	2.5019 2.5010	2.0625	3.50	22	.50		5.7515 5.7500	5.7500 5.7495
						ROLLWAY	MDW 313	5.5118	2.5591 2.5585	1.2992	2.3125	20	.625	.0012 " .0003 "	4.7520 4.7500	4.7500 4.7495
						S.K.F.										
						TIMKEN										
G.E.	MD103	86	13	800	5.25	NORMA HOFFMAN	R-365	5.5118	2.5591	1.299	1.299	14	.625	.0012 TIGHT .0003 "	4.7520 4.7500	4.7500 4.7495
						HYATT	" 313	5.5135 5.5116	2.5603 2.5594	2.1875	2.1875	15	.8125			
						ROLLWAY	MS 5313	5.5118	2.5591	2.3125	2.3125	14	.625		4.627 4.625	4.628 4.625
						S.K.F.	52313	5.5118	2.5591	1.8898	2.3125	28	.75	-.0014 -.0002	"	"
						TIMKEN	8313	5.5118 5.5110	2.5591 2.5585	2.3175 2.3075	2.3175 2.3075	32	.703	.0015 TIGHT .0003" "	"	"
W.E.M.	MC 30	90	12	700	4.29	NORMA HOFFMAN	WIR365L	5.5118	2.5591	1.299	2.3125	14	.625		"	"

TABLE A-1

Motor Data						Bearing Data											
M'f'G.	Frame	Torque	H.P.	R.P.M.	Min. Pin. Dia.	M'f'G.	Series	A	B	C	D	Rollers No.	Rollers Dia.	Shaft Fit	Cart'g. O.D.	Frame Bore
G.E.	MD406	121	15	650	5.00	Hyatt	"313	5.5133 5.5118	2.5603 2.5598	2.1875	2.1675 2.1575	15	.8125	.0019 Tight .0005 "		5.5128 5.5123
						Rollway	MS-5313	5.5118 5.5110	2.5591 2.5585	2.3125	2.3125	14	.625	.0013 " .0002 "		5.5130 5.5130
						S.K.F.	22313	5.5118 5.5110	2.5591 2.5585	1.890	1.890	28	.75	.0018 " .0007 "		5.5128 5.5123
						Timken	8313	5.5118 5.5110	2.5591 2.5585	2.3175 2.3075	2.3175 2.3075	32	.703	.0018 Tight .0003 "		5.5128 5.5123
						Norma Hoffman	R-365	5.5118 5.5112	2.6595 2.5587	1.2990 1.2970	1.2990 1.2970	14	.625	.0016 " .0005 "		5.5118 5.5123
C.W.	BW	135	16	620	4.75	Hyatt	T-312	5.1185 5.1181	2.5009 2.5000	2.0625	3.50	15	.75	.0015 Tight .0001 "	4.4390 4.4380	4.4400 4.4380
						Rollway	MDW313	5.5118 5.5111	2.5591 2.5585	1.2992	2.3125	20	.625	.0015 " .0004 "	4.4390 4.4370	"
						S.K.F.	22312	5.1181	2.5002 2.4996	1.8110	1.8110	28	.75	.0018 " .0007 "	4.4380 4.4360	"
						Timken	8312	5.1181 5.1173	2.3622 2.3616	2.1300 2.1200	2.1300 2.1200	28	.703	.0015 Tight .0003 "		"
						Norma Hoffman	R365-L	5.5118	2.5591	1.299	1.299	14	.625	.0015 " .0004 "		"
G.E.	MD104	145	20	725	6.00	Hyatt	MW215	5.1185 5.1181	3.0000 2.9990	2.625	2.625	24	.50		6.1265 6.1250	6.1250 6.1245
						Rollway	MDW315	6.2992	2.9528	1.4567	2.6875	21	.687	.0012 " .0003 "	4.5050 4.5010	4.5000 4.4995
						S.K.F.										
						Timken										
						Norma Hoffman	R-375	6.2992	2.9528	1.457	1.457	14	.75	.0012 Tight .0003 "	4.5050 4.5010	4.5000 4.4995
W.E.M	MC40	176	20	600	5.00	Hyatt	"315	6.3011 6.2989	2.9542 2.9532	2.4375	2.4375	15	.9375		5.2520 5.2500	5.253 5.250
						Rollway	MS5315	6.2992	2.9528	2.6875	2.6875	14	.687		"	"
						S.K.F.	52315	6.2992	2.9528	2.1654	2.6875	30	.83	-.0015 -.0003	"	"
						Timken	8315	6.2992 6.2980	2.9528 2.9522	2.6925 2.6825	2.6925 2.6825	32	.812	.0015 Tight .0003 "	"	"
						Norma Hoffman	WIR375-L	6.2992	2.9528	1.457	2.6875	14	.75		"	"
C.W.	CW	226	25	590	5.33	Hyatt	TW215	5.1185 5.1181	3.0000 3.0000	2.625	3.375	24	.50	.0015 Tight .0001 "	5.2510 5.2500	5.2520 5.2500
						Rollway	MDW316	6.6925 6.6917	3.1496 3.1490	1.5354	2.6875	21	.750	.0015 " .0004 "	5.2520 5.2500	"
						S.K.F.	22315	6.2992	3.0003 2.9997	2.165	2.165	38	.83	.0018 " .0007 "	5.2500 5.2480	"
						Timken	8315	6.2992 6.2980	2.9528 2.9522	2.6925 2.6825	2.6925 2.6825	32	.812	.0015 Tight .0003 "		"
						Norma Hoffman	R-380-L	6.6929	3.1496	1.5350	1.5350	15	.75	.0015 " .0004 "		"
G.E.	MD408	228	25	575	5.67	Hyatt	"316	6.6949 6.6926	3.1458 3.1489	2.5625	2.5425 2.5325	15	1	.0018 " .0004 "		6.6939 6.6934
						Rollway	MS-5316	6.6929 6.6917	3.1496 3.1490	2.6875	2.6875	15	.750	.0014 " .0003 "		6.6965 6.6945
						S.K.F.	22316	6.6929 6.6917	3.1496 3.1490	2.2830	2.2830	28	.94	.0017 " .0006 "		6.6939 6.6934
						Timken	8316	6.6929 6.6917	3.1496 3.1490	2.6925 2.6825	2.6825	28	.922	.0015 Tight .0003 "		6.6939 6.6934
						Norma Hoffman	R-380	6.6925 6.6923	3.1458 3.1492	1.5350 1.5330	1.5350	15	.75	.0015 " .0004 "		6.6939 6.6934
G.E.	MD104½	252	30	625	6.33	Hyatt	MW215	5.1195 5.1181	3.0000 2.9990	2.625	2.625	24	.50		6.1265 6.1250	6.1250 6.1245
						Rollway	MDW315	6.2992	2.9528	1.4567	2.6875	21	.687	.0012 " .0003 "	4.5050 4.5010	4.5000 4.4995
						S.K.F.										
						Timken										
						Norma Hoffman	R-375	6.2992	2.9528	1.457	1.457	14	.75	.0012 Tight .0003 "	4.5050 4.5010	4.5000 4.4995
W.E.M	MC50	300	30	525	5.00	Hyatt	"315	6.3011 6.2989	2.9542 2.9532	2.4375	2.4375	15	.9375		5.252 5.250	5.2530 5.2500
						Rollway	MS5315	6.2992	2.9528	2.6875	2.6875	14	.687		"	"
						S.K.F.	52315	6.2992	2.9528	2.1654	2.6875	30	.83	-.0015 " -.0003 "	"	"
						Timken	8315	6.2992 6.2980	2.9528 2.9522	2.6925 2.6825	2.6925 2.6825	32	.812	.0015 Tight .0003 "	"	"
						Norma Hoffman	WIR375-L	6.2992	2.9528	1.457	2.6875	14	.75		"	"
C.W.	DW	334	36	565	5.66	Hyatt	TW215	5.1185 5.1181	3.0009 3.0000	2.625	3.375	24	.50	.0015 Tight .0001 "	5.2510 5.2500	5.2520 5.2500
						Rollway	MDW316	6.6929 6.6917	3.1496 3.1490	1.5354	2.6875	21	.750	.0015 " .0004 "	5.2520 5.2500	"
						S.K.F.	22315	6.2992	3.0003 2.9997	2.1650		30	.83	.0018 " .0007 "	5.2500 5.2490	"
						Timken	8315	6.2992 6.2980	2.9528 2.9522	2.6925 2.6825	2.6925 2.6825	32	.812	.0015 Tight .0003 "		"
						Norma Hoffman	R-380-L	6.6929	3.1496	1.535	1.535	15	.75	.0015 " .0004 "		"
G.E.	MD410	350	35	525	6.00	Hyatt	"317	7.0883 7.0866	3.3468 3.3453	2.75	2.7300 2.7200	16	1	.0017 " .0002 "		7.0877 7.0872
						Rollway	MS-5317	7.0866 7.0854	3.3463 3.3458	2.875	2.875	13	.875	.0015 " .0003 "		7.0902 7.0882
						S.K.F	22317	7.0866 7.0854	3.3465 3.3458	2.362	2.362	28	.98	.0017 " .0005 "		7.0877 7.0872
						Timken	8317	7.0866 7.0854	3.3465 3.3458	2.8800 2.8700	2.8800 2.8700	32	.922	.0017 Tight .0005 "		7.0877 7.0872
						Norma Hoffman	R-385	7.0866 7.0860	3.3467 3.3461	1.6140 1.6120	1.6140 1.6120	14	.875	.0014 " .0003 "		7.0877 7.0872
G.E.	MD105	383	40	550	5.66	Hyatt	MW215	5.1195 5.1181	3.0000 2.9990	2.625	2.625	24	.50		5.0010 5.0000	5.0020 4.9990
						Rollway	MDW315	6.2992 6.2980	2.9528 2.9523	1.4567	2.6875	21	.687	.0012 " .0003 "	5.0040 5.0010	5.0020 4.9990
						S.K.F.	22315	6.2992	2.9528	2.165	2.165	30	.83	.0017 " .0003 "	5.0040 5.0010	5.0020 4.9990
						Timken										
						Norma Hoffman	R-375	6.2992	2.9528	1.457	1.457	14	.75	.0012 " .0003 "	5.0040 5.0010	5.0020 4.9990
G.E.	MD105	383	40	550	5.66	Hyatt	TW220	7.0883 7.0866	4.0011 4.0000	3.25	4.375	22	.75	.0020 Tight .0004 "	6.5010 6.5000	6.502 6.500
						Rollway	MDW321			1.9291	3.4375	18	1.125	.0016 " .0006 "	6.5020 6.5000	"
						S.K.F.	22320	8.4646	4.0005 3.9998	2.874	2.874			.0022 " .0010 "	6.5000 6.4980	"
						Timken	8320	8.4646 8.4634	3.9370 3.9363	3.2550 3.2450	3.2550 3.2450	28	1.141	.0017 Tight .0003 "		"
C.W.	EW	450	47	550	6.00	Norma Hoffman	R405-L	8.8583	4.1339	1.9290	1.9290	16	1	.0016 " .0006 "		"

TABLE A-2

Motor Data						Bearing Data											
M'f'G.	Frame	Torque	H.P.	R.P.M.	Min. Pin. Dia.	M'f'G.	Series	A	B	C	D	Roller No.	Roller Dia	Shaft Fit	Cartg O.D.	Frame Bore
G.E.	MD412	525	50	500	6.33	Hyatt	*319	7.8758 7.8740	3.7405 3.7395	3.125	3.1050 3.0950	16	1.125	.0020 Tight .0005 "		7.8750 7.8745
						Rollway	MS5319	7.8741 7.8729	3.7402 3.7395	3.0625	3.0625	15	.875	.0015 " .0003 "		7.8776 7.8756
						S.K.F.	22319	7.8740 7.8728	3.7402 3.7395	2.6378	2.637	30	1.06	.0020 " .0008 "		7.8750 7.8745
						Timken	8319	7.8740 7.8728	3.7402 3.7395	3.0675 3.0575	3.0675 3.0575	32	1.031	.0017 Tight .0003 "		7.8750 7.8745
						Norma Hoffman	R 395	7.8740 7.8734	3.7404 3.7398	1.7720 1.7700	1.7720 1.7700	16	.875	.0017 " .0006 "		7.8750 7.8745
W.E.M.	MC60	540	50	525	6.00	Hyatt	* 319	7.8763 7.8736	3.7420 3.7408	3.125	3.125	16	1.125		6.2520 6.2500	6.2530 6.2500
						Rollway	MS5319	7.8740	3.7402	3.0625	3.0625	15	.875		"	"
						S.K.F.	52319	7.8740	3.7402	2.6378	3.0625	30	1.06	-.0020 " -.0006 "	"	"
						Timken	8319	7.8740 7.8728	3.7402 3.7395	3.0675 3.0575	3.0675 3.0575	32	1.031	.0017 Tight .0003 "	"	"
						Norma Hoffman	WIR395L	7.8740	3.7402	1.772	3.0625	16	.875		"	"
C.W.	F.W.	660	66	525	6.40	Hyatt	TW220	7.0883 7.0866	4.0011 4.0000	3.25	4.375	22	.75	.0020 Tight .0004 "	6.5010 6.5000	6.5020 6.5000
						Rollway	MDW321	8.8583 8.8571	4.1339 4.1332	1.9291	3.4375	18	1.125	.0016 " .0006 "	6.5020 6.5000	"
						S.K.F.	22320	8.4646	4.0005 3.9998	2.874	2.874	28	1.22	.0022 " .0010 "	6.5000 6.4980	"
						Timken	8320	8.4646 8.4634	3.9370 3.9363	3.2550 3.2450	3.2550 3.2450	28	1.141	.0017 Tight .0005 "		"
						Norma Hoffman	R405 L	8.8583	4.1339	1.929	1.929	16	1	.0016 " .0006 "		"
G.E.	MD106	735	70	500	6.80	Hyatt	MW220	7.0883 7.0866	4.0000 3.9987	3.25	3.25	22	.75		6.2510 6.2500	6.2520 6.2490
						Rollway	MDW320	8.4646 8.4634	3.9370 3.9363	1.8504	3.25	20	1.00	.0017 " .0005 "	6.2540 6.2520	6.2530 6.2490
						S.K.F.	22320	8.4646	3.9370	2.874	2.874	28	1.22	.0017 " .0003 "	6.2540 6.2500	6.2520 6.2490
						Timken	8320	8.4646 8.4634	3.9370 3.9363	3.2550 3.2450	3.2550 3.2450	28	1.141	.0017 Tight .0003 "	6.2510 6.2500	6.2520 6.2490
						Norma Hoffman	R400	8.4646	3.9370	1.850	1.850	14	1	.0017 " .0003 "	6.2510 6.2500	6.2520 6.2490
W.E.M	MC70	480	70	475	6.00	Hyatt	*319	7.8763 7.8736	3.7420 3.7408	3.125	3.125	16	1.125		6.252 6.250	6.253 6.250
						Rollway	MS5319	7.8740	3.7402	3.0625	3.0625	15	.875		"	"
						S.K.F.	52319	7.8740	3.7402	2.6378	3.0625	30	1.06	-.0020 -.0006	"	"
						Timken	8319	7.8740 7.8728	3.7402 3.7395	3.0675 3.0575	3.0675 3.0575	32	1.031	.0017 Tight .0003 "	"	"
						Norma Hoffman	WIR395L	7.8740	3.7402	1.772	3.0625	16	.875		"	"
G.E.	MD414	830	75	475	7.20	Hyatt	*322	9.4509 9.4489	4.3310 4.3299	3.750	3.7300 3.7200	15	1.375	.0021 " .0005 "		9.4502 9.4492
						Rollway	MS5322	9.4489 9.4477	4.3307 4.3300	3.625	3.625	15	1.125	.0016 " .0004 "		9.4524 9.4504
						S.K.F.	22322	9.4488 9.4476	4.3307 4.3300	3.150	3.150	28	1.38	.0020 " .0008 "		9.4502 9.4492
						Timken	8322	9.4489 9.4477	4.3307 4.3300	3.6300 3.6200	3.6300 3.6200	28	1.25	.0017 Tight .0003 "		9.4502 9.4492
						Norma Hoffman	R410	9.4488 9.4482	4.3309 4.3303	1.9690 1.9670	1.9690 1.9670	14	1.125	.0017 " .0006 "		9.4502 9.4492
G.E.	MD107	895	85	500	7.60	Hyatt	TW222	7.8758 7.8740	4.5028 4.5014	3.50	4.375	21	.875		7.0010 7.0000	7.0020 6.9990
						Rollway	MDW622S	9.4488	4.4993 4.4986	1.9685	3.625	20	1.125	.0016 " .0004 "	7.0040 7.0000	7.0020 6.9990
						S.K.F.										
						Timken										
						Norma Hoffman										
C.W.	GW	940	90	500	8.00	Hyatt	TW222	7.8758 7.8740	4.5028 4.5014	3.500	4.375	21	.875	.0020 Tight .0004 "	7.001 7.000	7.002 7.000
						Rollway	MDW324	9.8426 9.8411	4.7244 4.7236	2.0473	3.75	21	1.125	.0016 " .0006 "	7.002 7.000	"
						S.K.F.	22322	9.4488	4.5007 4.5000	3.150	3.150	28	1.38	.0022 " .0010 "	7.000 6.998	"
						Timken	8322	9.4489 9.4477	4.3307 4.3300	3.6300 3.6200	3.6300 3.6200	28	1.25	.0017 Tight .0003 "		"
						Norma Hoffman	R420 L	10.2362	4.7244	2.165	2.165		1.125	.0016 " .0006 "		"
W.E.M	MC80	960	85	480	6.80	Hyatt	*322	9.4514 9.4484	4.3327 4.3313	3.75	3.75	15	1.375		7.002 7.000	7.003 7.000
						Rollway	MS5322	9.4489	4.3307	3.625	3.625	15	1.125		"	"
						S.K.F.	52322	9.4488	4.3307	3.1496	3.625	28	1.38	-.0020 -.0006	"	"
						Timken	8322	9.4489 9.4477	4.3307 4.3300	3.6300 3.6200	3.6300 3.6200	28	1.25	.0017 Tight .0003 "	"	"
						Norma Hoffman	WIR410L	9.4488	4.3307	1.969	3.625	14	1.125		"	"
W.E.M	MC90	1050	100	500	7.20	Hyatt	* 324	10.2385 10.2356	4.7266 4.7251	4.125	4.125	16	1.375		7.377 7.375	7.378 7.375
						Rollway	MS5324	10.2362	4.7244	4.125	4.125	15	1.125		"	"
						S.K.F.	52324	10.2362	4.7244	3.3858	4.125	28	1.50	-.0025 -.0009	"	"
						Timken	8324	10.2363 10.2351	4.7244 4.7236	4.1300 4.1200	4.1300 4.1200	28	1.344	.0019 Tight .0005 "	"	"
						Norma Hoffman	WIR420L	10.2362	4.7244	2.1654	4.125	16	1.125		"	"
G.E.	MD108	1050	100	500	8.80	Hyatt	TMW226	8.4665 8.4646	5.0031 5.0016	3.875	4.875	27	.75		8.0010 8.0000	8.0020 7.9990
						Rollway	MDW626	10.2363 10.2351	4.5989 4.9982	2.1260	3.875	22	1.125	.0020 Tight .0008 "	8.0040 8.0020	8.0020 7.9990
						S.K.F.										
						Timken										
						Norma Hoffman	RMS23	10.000	5.000	2.000	2.000	16	1.125		8.0010 8.0000	8.0020 7.9990
G.E.	MD416	1140	100	460	8.00	Hyatt	* 324	10.2385 10.2362	4.7247 4.7236	4.125	4.1050 4.0950	16	1.375	.0024 " .0008 "		10.2376 10.2366
						Rollway	MS5324	10.2363 10.2351	4.7244 4.7236	4.125	4.125	15	1.125	.0019 " .0005 "		10.2385 10.2379
						S.K.F.	22324	10.2362 10.2350	4.7244 4.7236	3.386	3.386	28	1.50	.0024 " .0011 "		10.2374 10.2366
						Timken	8324	10.2363 10.2351	4.7244 4.7236	4.1300 4.1200	4.1300 4.1200	28	1.344	.0019 Tight .0003 "		10.2376 10.2366
						Norma Hoffman	R420	10.2362	4.7244	2.165	2.165		1.125			10.2376 10.2366

TABLE A-3

Motor Data						Bearing Data										
M'f'G	Frame	Torque	H.P.	RPM	Min.Pin. Dia	M'f'G	Series	A	B	C	D	Roller No	Roller Dia	Shaft Fit	Cart'g O.D.	Frame Bore
C.W.	H.W	1350	120	465	8.66	Hyatt	TMW226	8.4665 8.4646	5.0012 5.0000	3.875	4.875	27	.75	.0020 Tight .0004 "	8.0010 8.0000	8.0020 8.0000
						Rollway	MDW326	10.2368 10.2351	5.1181 5.1173	2.1260	3.875	22	1.125	.0021 " .0006 "	8.0020 8.0000	"
						S.K.F	22324	10.2363	5.0010 5.0002	3.386	3.386	28	1.50	.0020 " .0008 "	8.0000 7.9980	"
						Timken	8324	10.2363 10.2351	4.7244 4.7236	4.1300 4.1200	4.1300 4.1200	28	1.344	.0019 Tight .0003 "		"
						Norma Hoffman	RMS23-L	10.000	5.000	2.000	2.000	16	1.125	.0021 " .0006 "		"
G.E.	MD418	1750	150	450	9.00	Hyatt	W226	9.0571 9.0551	5.1185 5.1173	4.250	4.2300 4.2200	21	1	.0024 " .0007 "		9.0566 9.0556
						Rollway	MS5326	11.0237 11.0221	5.1181 5.1171	4.375	4.375	15	1.250	.0025 " .0004 "		11.0279 11.0259
						S.K.F.	22326	11.0236 11.0224	5.1181 5.1173	3.6610	3.6610	28	1.61	.0024 " .0011 "		11.0279 11.0256
						Timken	8326	11.0237 11.0221	5.1181 5.1171	4.3800 4.3700	4.3800 4.3700	28	1.438	.0021 Tight .0003 "		11.0279 11.0256
						Norma Hoffman	R430	11.0236	5.1181	2.3228	2.3228	15	1.25			
W.E.M	MC103	1990	180	475	8.80	Hyatt	326	9.0576 9.0546	5.1205 5.1189	4.2500	4.2500		1.00		8.2520 8.2500	8.2530 8.2500
						Rollway	MS5326	11.0236	5.1181	4.375	4.375	15	1.250		"	8.2530 8.2500
						S.K.F.	52326	11.0236	5.1181	3.6614	4.375	28	1.61	-.0025 -.0009	"	"
						Timken	8326	11.0237 11.0221	5.1181 5.1171	4.3800 4.3700	4.3800 4.3700	28	1.438	.0021 Tight .0003 "	"	"
						Norma Hoffman	WIR430L	11.0236	5.1181	2.3228	4.375	15	1.25			
W.E.M	MC100	2100	150	370	8.00	Hyatt	326	9.0576 9.0546	5.1205 5.1189	4.2500	4.2500		1.00		8.2520 8.2500	8.2530 8.2500
						Rollway	MS5326	11.0236	5.1181	4.375	4.375	15	1.250			8.2530 8.2500
						S.K.F.	52326	11.0236	5.1181	3.6614	4.375	28	1.61	-.0025 -.0009	"	"
						Timken	8326	11.0237 11.0221	5.1181 5.1171	4.3800 4.3700	4.3800 4.3700	28	1.438	.0021 Tight .0003 "	"	"
						Norma Hoffman	WIR430L	11.0236	5.1181	2.3228	4.375	15	1.25			
C.W.	IW	2140	175	430	10.00	Hyatt	W228	9.8451 9.8419	5.3144 5.3127	4.75	4.75	22	1.0625	.0015 Tight .0008 "		8.6270 8.6250
						Rollway	MDW328	10.4331 10.4316	5.5115 5.5111	2.2047	4.125	20	1.250	.0020 " .0007 "	8.6270 8.6250	"
						S.K.F										"
						Timken	8328	11.8111 11.8095	5.5118 5.5108	4.5050 4.4950	4.5050 4.4950	28	1.531	.0022 Tight .0003 "		"
						Norma Hoffman	RMS23½L	11.000	5.500	2.000	2.000	17	1.125	.0016 " .0005 "		"
G.E.	MD109	2300	175	400	10.50	Hyatt	MW230	10.6380 10.6299	6.0000 5.9982	4.75	4.75	21	1.1875		9.5010 9.5000	9.5020 9.4990
						Rollway	MW31.004									
						S.K.F.										
						Timken										
						Norma Hoffman	RMS24	12.000	6.000	2.250	2.250	16	1.25			
W.E.M	165	3300	2.75	42.5		Hyatt	D-228 D-232									
						Rollway										
						S.K.F.										
						Timken	Δ 99587-35100 34700-34113	10.0000-.0004 11.375-.376	5.8759-60 7.0009-10	1.8750 1.8750	2.6250 2.5000	19 23	.980 .980		20.500 20.499	
						Norma Hoffman										
G.E.	MDS103½	3340	2.55	400	10.50	Hyatt	MW230	10.6380 10.6299	6.0000 5.9982	4.75	4.75	21	1.1875		9.5010 9.5000	9.5020 9.4990
						Rollway	MW31.004									
						S.K.F.										
						Timken										
						Norma Hoffman	RMS24	12.000	6.000	2.250	2.250	16	1.25			
G.E.	MDS420	3350	2.75	375		Hyatt	W230	10.6320 10.6299	5.9055 5.9046	4.750	4.7300 4.7200	21	1.1875	.0026 Tight .0008 "		10.6314 10.6304
						Rollway	MS5330	12.5984 12.5968	5.9055 5.9045	4.875	4.875	15	1.50	.0026 " .0006 "		12.6027 12.6007
						S.K.F.	22330	12.5984 12.5972	5.9055 5.9047	4.252	4.252	28	1.85	.0025 " .0012 "		12.6027 12.6004
						Timken	8330	12.5985 12.5969	5.9055 5.9045	4.8800 4.8700	4.8800 4.8700	28	1.625	.0022 Tight .0003 "		12.6027 12.6004
						Norma Hoffman										
G.E.	MDS110	4430	2.95	350		Hyatt										
						Rollway										
						S.K.F.										
						Timken										
						Norma Hoffman										

Δ Two Bearings On Commutator End
+ Two Bearings On Pinion End

LEGEND:-

Data On Bearing Dimensions, Fits, Tolerance, Etc., Obtained From The Following Publications. Supplemented Thru Correspondence With The Various Bearing Manufacturers.

Manufacturer	Publication	Cat. Nº	Data
1-Hyatt Roller Bearing Co.	Dimension & Load Bulletin	Form 1559	Sept. 1928
2-Rollway Bearing Co.	Engineering Data Sheets		
3-SKF Industries Inc.	Engineering Data Sheets		1928
4-Timken Roller Bearing Co.	Engineering Data Sheets		Jan. 1928
5-Norma Hoffman Bearing Co.	Engineering Data Sheets	Cat.# 917	1927
6-W.E. & Mfg. Co.	Engineering Blue Prints		
7-G.E. Co.	Engineering Blue Prints		

TABLE A-4

Roller Bearing Shaft Fits

S.A.E. St'd.					Westinghse Adaption				Hyatt Adaption			
Bearing	Bearing	Shaft	Fit		Bearing	Shaft	Fit		Bearing	Shaft	Fit	
No	Bore	Dia.	Max.	Min.	Bore	Dia.	Max.	Min.	Bore	Dia.	Max.	Min.
310	1.9685 1.9680	1.9686 1.9690	-.0010	-.0001	1.9685 1.9680	1.9685 1.9690	-.0010	+.0000	1.9687 1.9679	1.9688 1.9695	-.0016	-.0001
313	2.5591 2.5585	2.5593 2.5598	-.0013	-.0002	2.5591 2.5585	2.5590 2.5595	-.0010	+.0001	2.5593 2.5584	2.5594 2.5603	-.0019	-.0001
315	2.9528 2.9522	2.9530 2.9535	-.0013	-.0002	2.9528 2.9522	2.9530 2.9535	-.0013	-.0002	2.9530 2.9521	2.9532 2.9542	-.0021	-.0002
319	3.7402 3.7395	3.7405 3.7410	-.0015	-.0003	3.7402 3.7395	3.7405 3.7410	-.0015	-.0003	3.7404 3.7394	3.7408 3.7420	-.0026	-.0004
322	4.3307 4.3300	4.3311 4.3316	-.0015	-.0003	4.3307 4.3300	4.3310 4.3315	-.0015	-.0003	4.3309 4.3298	4.3313 4.3327	-.0029	-.0004
324	4.7244 4.7236	4.7249 4.7255	-.0019	-.0006	4.7244 4.7236	4.7250 4.7255	-.0019	-.0006	4.7246 4.7235	4.7251 4.7266	-.0031	-.0005
326	5.1181 5.1171	5.1187 5.1193	-.0017	-.0004	5.1181 5.1173	5.1185 5.1190	-.0017	-.0004				
99587 -99100	5.875 5.876	5.8765 } Adj. 5.8755 } 5.8770 } Non 5.8760 } Adj.			5.875 5.876	5.8755 } Adj. 5.8750 } 5.8770 } Non 5.8760 } Adj.						
94700 -94113	7.000 7.001				7.000 7.001	7.0005 } Adj. 7.0000 } 7.0010 } Non 7.0010 } Adj.						

Roller Bearing Cartridge Fits

	Bearing	Cartridge	Fit		Bearing	Cartridge	Fit		Bearing	Cartridge	Fit	
	O.D.	Bore	Max.	Min.	O.D.	Bore	Max.	Min.	O.D.	Bore	Max.	Min.
310	4.3307 4.3299	4.3319 4.3339	+.0040	+.0012	4.3307 4.3299	4.3309 4.3322	+.0023	+.0002	4.3320 4.3307	4.3306 4.3322	-.0015	+.0014
313	5.5118 5.5110	5.5130 5.5150	+.0040	+.0012	5.5118 5.5110	5.5120 5.5133	+.0023	+.0002	5.5133 5.5118	5.5116 5.5135	-.0017	+.0017
315	6.2992 6.2980	6.3008 6.3028	+.0046	+.0016	6.2992 6.2980	6.2995 6.3010	+.0030	+.0003	6.3008 6.2992	6.2989 6.3011	-.0019	+.0019
319	7.8741 7.8729	7.8756 7.8776	+.0047	+.0015	7.8741 7.8729	7.8745 7.8762	+.0033	+.0004	7.8758 7.8740	7.8736 7.8763	-.0023	+.0022
322	9.4489 9.4477	9.4504 9.4524	+.0047	+.0015	9.4489 9.4477	9.4493 9.4510	+.0033	+.0004	9.4509 9.4489	9.4484 9.4514	-.0025	+.0025
324	10.2363 10.2351	10.2379 10.2399	+.0048	+.0016	10.2362 10.2350	10.2367 10.2385	+.0035	+.0005	10.2383 10.2362	10.2356 10.2389	-.0027	+.0027
326	11.0237 11.0221	11.0259 11.0279	+.0058	+.0022	11.0236 11.0224	11.0242 11.0260	+.0036	+.0006				
99587 -99100	10.000 10.001	10.000 10.001			10.000 10.001	10.001 10.002						
94700 -94113	11.375 11.376				11.375 11.376							

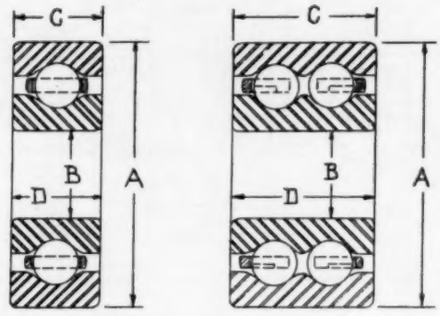
NOTE:- Negative Implies Interference Or "Press Fit."
Positive Implies Looseness Or "Slip Fit."

Table B

Crocker Wheeler Shaft Fits							Cartridge Fits			
Motor Frame	Bearing Mf'g.	Bearing No.	Bearing Bore	Shaft Dia.	Fits Max.	Fits Min.	Frame Bore	Cartridge Dia.	Fits Max.	Fits Min.
AW	Hyatt	T-310	2.0008 2.0000	2.0015 2.0010	-.0015	-.0002	3.9400 3.9380	3.9390 3.9380	+.0020	-.0010
	Rollway	MDW-311	2.1654 2.1649	2.1663 2.1660	-.0014	-.0006	3.9400 3.9380	3.9400 3.9380	+.0020	-.0020
	S.K.F.	22310	2.0005 2.0000	2.0015 2.0010	-.0015	-.0005	3.9400 3.9380	3.9380 3.9360	+.0040	-.0000
	Hoffman	R-355-L	2.1654 2.1649	2.1663 2.1660	-.0014	-.0006				
	Timken									
BW	Hyatt	T-312	2.5009 2.5000	2.5015 2.5010	-.0015	-.0001	4.4400 4.4380	3.9390 3.9380	+.0020	-.0010
	Rollway	MDW-313	2.5591 2.5585	2.5610 2.5600	-.0025	-.0009	4.4400 4.4380	3.9400 3.9380	+.0020	-.0020
	S.K.F.	22312	2.5002 2.4996	2.5015 2.5010	-.0019	-.0008	4.4400 4.4380	3.9380 3.9360	+.0040	-.0000
	Hoffman	R-365-L	2.5591 2.5585	2.5610 2.5600	-.0025	-.0009				
	Timken									
CW DW	Hyatt	TW-215	3.0000 3.0000	3.0015 3.0010	-.0015	-.0010	5.2520 5.2500	5.2510 5.2500	+.0020	-.0010
	Rollway	MDW-316	3.1496 3.1490	3.1505 3.1500	-.0015	-.0004	5.2520 5.2500	5.2520 5.2500	+.0020	-.0020
	S.K.F.	22315	3.0003 2.9997	3.0015 3.0010	-.0018	-.0007	5.2520 5.2500	5.2500 5.2480	+.0040	-.0000
	Hoffman	R-380-L	3.1496 3.1490	3.1505 3.1500	-.0015	-.0004				
	Timken									
EW FW	Hyatt	TW-220	4.0011 4.0000	4.0020 4.0015	-.0020	-.0004	6.5020 6.5000	6.5010 6.5000	+.0020	-.0010
	Rollway	MDW-321	4.1339 4.1332	4.1350 4.1345	-.0018	-.0006	6.5020 6.5000	6.5020 6.5000	+.0020	-.0020
	S.K.F.	22320	4.0005 3.9998	4.0020 4.0015	-.0022	-.0010	6.5020 6.5000	6.5000 6.4980	+.0040	-.0000
	Hoffman	R-405-L	4.1339 4.1332	4.1350 4.1345	-.0018	-.0006				
	Timken									
GW	Hyatt	TW-222	4.5028 4.5014	4.5020 4.5015	-.0006	+.0013	7.0020 7.0000	7.0010 7.0000	+.0020	-.0010
	Rollway	MDW-324	4.7244 4.7236	4.7255 4.7250	-.0019	-.0006	7.0020 7.0000	7.0020 7.0000	+.0020	-.0020
	S.K.F.	22322	4.5007 4.5000	4.5020 4.5015	-.0020	-.0008	7.0020 7.0000	7.0000 6.9980	+.0040	-.0000
	Hoffman	R-420-L	4.7244 4.7236	4.7255 4.7250	-.0019	-.0006				
	Timken									
HW	Hyatt	TMW-226	5.0012 5.0000	5.0025 5.0020	-.0025	-.0008	8.0020 8.0000	8.0010 8.0000	+.0020	-.0010
	Rollway	MDW-326	5.1181 5.1172	5.1200 5.1190	-.0028	-.0009	8.0020 8.0000	8.0020 8.0000	+.0020	-.0020
	S.K.F.	22324	5.0010 5.0002	5.0025 5.0020	-.0023	-.0010	8.0020 8.0000	8.0000 7.9980	+.0040	-.0000
	Hoffman	RMS-23-L	5.0000 4.9991	5.0012 5.0007	-.0021	-.0007				
	Timken									
IW	Hyatt	W-226	5.5144 5.5127	5.5135 5.5130	-.0008	+.0014				
	Rollway	MDW-328	5.5119 5.5111	5.5130 5.5125	-.0019	-.0006	8.6270 8.6250	8.6270 8.6250	+.0020	-.0020
	S.K.F.									
	Hoffman	RMS-23½-L	5.5000 5.5017	5.5032 5.5007	-.0015	-.0007				
	Timken									

NOTE :- Negative Implies Interference Or "Press Fit"
Positive Implies Looseness Or "Slip Fit"

Table B-1



Reliance A.C. Motors

Motor Data				Bearing Data												
Frame	Torque	H.P.	R.P.M.	M'f'g.	S.A.E. Bearing Size		Type	A	B	C	D	Balls No.	Balls Dia.	Shaft Dia.	Cart'g O.D.	Frame Bore
3AA	3	½	850	S.K.F Fafnir N.Departure S.R.B.	Pulley	306	Ball	2.8346	1.1811	.7480	.7480		.437	1.1814 1.1809	None	2.8350 2.8360
		¾	1150		O.E.	306	Ball	2.8346	1.1811	.7480	.7480		.437	1.1814 1.1809	"	2.8350 2.8360
		1	1750													
4½AA	4½	¾	850	"	Pulley	306	Ball	2.8346	1.1811	.7480	.7480		.437	1.1814 1.1809	"	2.8350 2.8360
		1	1150													
		1½	1750		O.E.	306	Ball	2.8346	1.1811	.7480	.7480		.437	1.1814 1.1809	"	2.8350 2.8360
6AA	6	1	850	"	Pulley	306	Ball	2.8346	1.1811	.7480	.7480		.437	1.1814 1.1809	"	2.8350 2.8360
		1½	1150													
		2	1750		O.E.	306	Ball	2.8346	1.1811	.7480	.7480		.437	1.1814 1.1809	"	2.8350 2.8360
9AA	9	1½	850	"	Pulley	307	Ball	3.1496	1.3780	.8268	.8268		.500	1.3783 1.3778	"	3.1500 3.1510
		2	1150													
		3	1750		O.E.	307	Ball	3.1496	1.3780	.8268	.8268		.500	1.3783 1.3778	"	3.1500 3.1510
15AA	15	2	850	"	Pulley	307	Ball	3.1496	1.3780	.8268	.8268		.500	1.3783 1.3778	"	3.1500 3.1510
		3	1150													
		5	1750		O.E.	307	Ball	3.1496	1.3780	.8268	.8268		.500	1.3783 1.3778	"	3.1500 3.1510
22AA	22	3	850	"	Pulley	309	Ball	3.9370	1.7717	.9843	.9843		.625	1.7720 1.7715	"	3.9370 3.9380
		5	1150													
		7½	1750		O.E.	309	Ball	3.9370	1.7717	.9843	.9843		.625	1.7720 1.7715	"	3.9370 3.9380
30AA	30	5	850	"	Pulley	309	Ball	3.9370	1.7717	.9843	.9843		.625	1.7720 1.7715	"	3.9370 3.9380
		7½	1150													
		10	1750		O.E.	309	Ball	3.9370	1.7717	.9843	.9843		.625	1.7720 1.7715	"	3.9370 3.9380
44AA	44	7½	850	"	Pulley	310	Ball	4.3307	1.9685	1.0630	1.0630		.687	1.9688 1.9683	"	4.3310 4.3320
		10	1150													
		15	1750		O.E.	310	Ball	4.3307	1.9685	1.0630	1.0630		.687	1.9688 1.9683	"	4.3310 4.3320
60AA	60	10	850	"	Pulley	310	Ball	4.3307	1.9685	1.0630	1.0630		.687	1.9688 1.9683	"	4.3310 4.3320
		15	1150													
		20	1750		O.E.	310	Ball	4.3307	1.9685	1.0630	1.0630		.687	1.9688 1.9683	"	4.3310 4.3320
73AA	73	10	850	"	Pulley	310	Ball	4.3307	1.9685	1.0630	1.0630		.687	1.9688 1.9683	"	4.3310 4.3320
		15	1150													
		25	1750		O.E.	310	Ball	4.3307	1.9685	1.0630	1.0630		.687	1.9688 1.9683	"	4.3310 4.3320
88AA	88	15	850	"	Pulley	314	Ball	5.9055	2.7559	1.3780	1.3780		.937	2.7562 2.7557	"	5.9055 5.9065
		20	1150													
		30	1750		O.E.	314	Ball	5.9055	2.7559	1.3780	1.3780		.937	2.7562 2.7557	"	5.9055 5.9065
118AA	118	20	850	"	Pulley	314	Ball	5.9055	2.7559	1.3780	1.3780		.937	2.7562 2.7557	"	5.9055 5.9065
		25	1150													
		40	1750		O.E.	314	Ball	5.9055	2.7559	1.3780	1.3780		.937	2.7562 2.7557	"	5.9055 5.9065
146AA	146	25	850	"	Pulley	414	Ball	7.0866	2.7559	1.6535	1.6535		1.25	2.7562 2.7557	"	7.0870 7.0880
		30	1150													
		50	1750		O.E.	414	Ball	7.0866	2.7559	1.6535	1.6535		1.25	2.7562 2.7557	"	7.0870 7.0880
176AA	176	30	850	"	Pulley	414	Ball	7.0866	2.7559	1.6535	1.6535		1.25	2.7562 2.7557	"	7.0870 7.0880
		40	1150													
		60	1750		O.E	414	Ball	7.0866	2.7559	1.6535	1.6535		1.25	2.7562 2.7557	"	7.0870 7.0880
220AA	220	40	850	"	Pulley	414	Ball	7.0866	2.7559	1.6535	1.6535		1.25	2.7562 2.7557	"	7.0870 7.0880
		50	1150													
		75	1750		O.E.	414	Ball	7.0866	2.7559	1.6535	1.6535		1.25	2.7562 2.7557	"	7.0870 7.0880
260AA	260	50	850	"	Pulley	317	Ball	7.0866	3.3465	1.6142	1.6535		1.125	2.7562 2.7557	"	7.0870 7.0880
		60	1150													
		75	1750		O.E.	414	Ball	7.0866	2.7559	1.6535	1.6535		1.25	2.7562 2.7557		7.0870 7.0880

60 Cycle Motors

Table C-1

Reliance A.C. Motors

Motor Data				Bearing Data												
Frame	Torque	H.P.	R.P.M.	M'f'g.	S.A.E. Bearing Size		Type	A	B	C	D	Balls No.	Balls Dia.	Shaft Dia.	Cartg. O.D.	Frame Bore
3AA	3	½	1500	S.K.F. Fafnir N. Departure S.R.B.	Pulley	306	Ball	2.8346	1.1811	.7480	.7480		.437	1.1814 1.1809	None	2.8350 2.8360
					O.E.	306	"	2.8346	1.1811	.7480	.7480		.437	1.1814 1.1809	"	2.8350 2.8360
4½AA	4½	½	750	"	Pulley	306	"	2.8346	1.1811	.7480	.7480		.437	1.1814 1.1809	"	2.8350 2.8360
					O.E.	306	"	2.8346	1.1811	.7480	.7480		.437	1.1814 1.1809	"	2.8350 2.8360
6AA	6	1	1500	"	Pulley	306	"	2.8346	1.1811	.7480	.7480		.437	1.1814 1.1809	"	2.8350 2.8360
		1½	1500		O.E.	306	"	2.8346	1.1811	.7480	.7480		.437	1.1814 1.1809	"	2.8350 2.8360
9AA 10AA	9	1	750	"	Pulley	307	"	3.1496	1.3780	.8268	.8268		.500	1.3783 1.3778	"	3.1500 3.1510
		2	1500		O.E.	307	"	3.1496	1.3780	.8268	.8268		.500	1.3783 1.3778	"	3.1500 3.1510
15AA 16AA	15	1½	750	"	Pulley	307	"	3.1496	1.3780	.8268	.8268		.500	1.3783 1.3778	"	3.1500 3.1510
		3	1500		O.E.	307	"	3.1496	1.3780	.8268	.8268		.500	1.3783 1.3778	"	3.1500 3.1510
22AA 24AA	22	3	750	"	Pulley	309	"	3.9370	1.7717	.9843	.9843		.625	1.7720 1.7715	"	3.9370 3.9380
		5	1500		O.E.	309	"	3.9370	1.7717	.9843	.9843		.625	1.7720 1.7715	"	3.9370 3.9380
31AA	30			"	Pulley	309	"	3.9370	1.7717	.9843	.9843		.625	1.7720 1.7715	"	3.9370 3.9380
		7½	1500		O.E.	309	"	3.9370	1.7717	.9843	.9843		.625	1.7720 1.7715	"	3.9370 3.9380
44AA 45AA	44	5	750	"	Pulley	310	"	4.3307	1.9685	1.0630	1.0630		.687	1.9688 1.9683	"	4.3310 4.3320
		10	1500		O.E.	310	"	4.3307	1.9685	1.0630	1.0630		.687	1.9688 1.9683	"	4.3310 4.3320
60AA	60	7½	750	"	Pulley	310	"	4.3307	1.9685	1.0630	1.0630		.687	1.9688 1.9683	"	4.3310 4.3320
					O.E.	310	"	4.3307	1.9685	1.0630	1.0630		.687	1.9688 1.9683	"	4.3310 4.3320
73AA 74AA	73	10	750	"	Pulley	310	"	4.3307	1.9685	1.0630	1.0630		.687	1.9688 1.9683	"	4.3310 4.3320
		15	1500		O.E.	310	"	4.3307	1.9685	1.0630	1.0630		.687	1.9688 1.9683	"	4.3310 4.3320
89AA	88	20	1500	"	Pulley	314	"	5.9055	2.7559	1.3780	1.3780		.937	2.7562 2.7557	"	5.9055 5.9065
					O.E.	314	"	5.9055	2.7559	1.3780	1.3780		.937	2.7562 2.7557	"	5.9055 5.9065
118AA 119AA	118	15	750	"	Pulley	314	"	5.9055	2.7559	1.3780	1.3780		.937	2.7562 2.7557	"	5.9055 5.9065
		25	1500		O.E.	314	"	5.9055	2.7559	1.3780	1.3780		.937	2.7562 2.7557	"	5.9055 5.9065
146AA	146	20	750	"	Pulley	414	"	7.0866	2.7559	1.6535	1.6535		1.25	2.7562 2.7557	"	7.0870 7.0880
					O.E.	414	"	7.0866	2.7559	1.6535	1.6535		1.25	2.7562 2.7557	"	7.0870 7.0880
176AA	176	25	750	"	Pulley	414	"	7.0866	2.7559	1.6535	1.6535		1.25	2.7562 2.7557	"	7.0870 7.0880
					O.E.	414	"	7.0866	2.7559	1.6535	1.6535		1.25	2.7562 2.7557	"	7.0870 7.0880
220AA	220	30	750	"	Pulley	414	"	7.0866	2.7559	1.6535	1.6535		1.25	2.7562 2.7557	"	7.0870 7.0880
					O.E.	414	"	7.0866	2.7559	1.6535	1.6535		1.25	2.7562 2.7557	"	7.0870 7.0880
260AA	260			"	Pulley	317	"	7.0866	3.3465	1.6142	1.6535		1.25	3.3468 3.3463	"	7.0870 7.0880
					O.E.	414	"	7.0866	2.7559	1.6535	1.6535		1.25	2.7562 2.7557	"	7.0870 7.0880

25 Cycle Motors

Table C-1a

RELIANCE D.C. MOTORS

MOTOR DATA				BEARING DATA												
FRAME	TORQUE	H.P.	R.P.M.	M'F'G.	S.A.E. BEARING	SIZE	TYPE	A	B	C	D	Nº	DIA.	SHAFT DIA.	CART'G O.D.	FRAME BORE
14T	14	2	850	S.K.F. FAFNIR N.DEPARTURE S.R.B.	PULLEY	309	BALL	3.9370	1.7717	.9843	.9843		.625	1.7720 1.7715	NONE	3.9370 3.9380
		3	1150													
		5	1750		COMM	307	"	3.1496	1.3780	.8268	.8268		.500	1.3783 1.3778	"	3.1500 3.1510
23T	23	3	850	"	PULLEY	309	"	3.9370	1.7717	.9843	.9843		.625	1.7720 1.7715	"	3.9370 3.9380
		5	1150													
		7½	1750		COMM	307	"	3.1496	1.3780	.8268	.8268		.500	1.3783 1.3778	"	3.1500 3.1510
34T	34	5	850	"	PULLEY	310	"	4.3307	1.9685	1.0630	1.0630		.687	1.9688 1.9683	"	4.3310 4.3320
		7½	1150													
		10	1750		COMM	309	"	3.9370	1.7717	.9843	.9843		.625	1.7720 1.7715	4.499 4.498	4.5010 4.5000
46T	46	7½	850	"	PULLEY	311	"	4.7244	2.1654	1.1417	1.1417		.750	2.1657 2.1652	NONE	4.7245 4.7255
		10	1150													
		15	1750		COMM	310	"	4.3307	1.9685	1.0630	1.0630		.687	1.9688 1.9683	"	4.3310 4.3320
66T	66	10	850	"	PULLEY	313	"	5.5118	2.5591	1.2992	1.2992		.875	2.5594 2.5589	"	5.5120 5.5130
		15	1150													
		20	1750		COMM	310	"	4.3307	1.9685	1.0630	1.0630		.687	1.9688 1.9683	"	4.3310 4.3320
78T	78	12	850	"	PULLEY	313	"	5.5118	2.5591	1.2992	1.2992		.875	2.5594 2.5589	"	5.5120 5.5130
		17	1150													
		26	1750		COMM	310	"	4.3307	1.9685	1.0630	1.0630		.687	1.9688 1.9683	"	4.3310 4.3320
92T	92	15	850	"	PULLEY	314	"	5.9055	2.7559	1.3780	1.3780		.937	2.7562 2.7557	"	5.9055 5.9065
		20	1150													
		30	1750		COMM	311	"	4.7244	2.1654	1.1417	1.1417		.750	2.1657 2.1652	"	4.7245 4.7255
131T	131	20	850	"	PULLEY	314	"	5.9055	2.7559	1.3780	1.3780		.937	2.7562 2.7557	"	5.9055 5.9065
		30	1150													
		40	1750		COMM	311	"	4.7244	2.1654	1.1417	1.1417		.750	2.1657 2.1652	"	4.7245 4.7255
185T	185	30	850	"	PULLEY	415	"	7.4803	2.9528	1.7717	1.7717		1.312	2.9531 2.9526	"	7.4805 7.4815
		40	1150													
		50	1750		COMM	313	"	5.5118	2.5591	1.2992	1.2992		.875	2.5594 2.5589	"	5.5120 5.5130
230T	230	37	850	"	PULLEY	415	"	7.4803	2.9528	1.7717	1.7717		1.312	2.9531 2.9526	"	7.4805 7.4815
		50	1150													
		60	1750		COMM	313	"	5.5118	2.5591	1.2992	1.2992		.875	2.5594 2.5589	"	5.5120 5.5130
262T	262	40	850	"	PULLEY	415	"	7.4803	2.9528	1.7717	1.7717		1.312	2.9531 2.9526	"	7.4805 7.4815
		50	1150													
		75	1750		COMM	313	"	5.5118	2.5591	1.2992	1.2992		.875	2.5594 2.5589	"	5.5120 5.5130
310T	310	50	850	"	PULLEY	417	"	8.2677	3.3465	2.0472	2.0472		1.50	3.3468 3.3463	"	8.2680 8.2690
		75	1150													
		100	1750		COMM	314	"	5.9055	2.7559	1.3780	1.3780		.937	2.7562 2.7557	"	5.9055 5.9065
385T	385	50	850	"	PULLEY	417	"	8.2677	3.3465	2.0472	2.0472		1.50	3.3468 3.3463	"	8.2680 8.2690
		84	1150													
		128	1750		COMM	314	"	5.9055	2.7559	1.3780	1.3780		.937	2.7562 2.7557	"	5.9055 5.9065
461T	461	75	850	TIMKEN * S.K.F. FAFNIR N.DEPARTURE	PULLEY	8319	ROLLER	7.8728 7.8740	3.7395 3.7402	3.0625	3.0625	32	1.031	3.7405 3.7400	12.247 12.246	12.2510 12.2500
		100	1150													
		154	1750		COMM	318	BALL	7.4803	3.5433	1.6929	1.6929		1.187	3.5436 3.5431	8.874 8.873	8.8740 8.8750
651T	651	100	850	TIMKEN * S.K.F. FAFNIR N.DEPARTURE	PULLEY	8319	ROLLER	7.8728 7.8740	3.7395 3.7402	3.0625	3.0625	32	1.031	3.7405 3.7400	12.247 12.246	12.251 12.250
		150	1150													
		217	1750		COMM	318	BALL	7.4803	3.5433	1.6929	1.6929		1.187	3.5436 3.5431	8.8740 8.8730	8.874 8.875
985T	985	159	850	TIMKEN * FAFNIR S.K.F. N.DEPARTURE	PULLEY	8319	ROLLER	7.8729 7.8741	3.7395 3.7402	3.0625	3.0625	32	1.031	3.7405 3.7400	12.247 12.246	12.251 12.250
		216	1150													
		328	1750		COMM	318	BALL	7.4803	3.5433	1.6929	1.6929		1.187	3.5436 3.5431	8.874 8.873	8.874 8.875
1050T	1050	150	850	HYATT * ‡	PULLEY	W224	ROLLER	8.4642 8.4670	4.7251 4.7266	3.8750	3.8750	21	.9375	4.7246 4.7241	11.750 11.749	11.752 11.750
		230	1150													
		350	1750		COMM	220	"	7.0863 7.0887	3.9376 3.9389	2.3125	2.3125	22	.750	3.9373 3.9368	9.9995 9.9990	10.001 10.000
1400T	1400	200	850	HYATT * ‡	PULLEY	W224	"	8.4642 8.4670	4.7251 4.7266	3.8750	3.8750	21	.9375	4.7246 4.7241	11.750 11.749	11.752 11.750
		306	1150													
		466	1750		COMM	220	"	7.0863 7.0887	3.9376 3.9389	2.3125	2.3125	22	.750	3.9373 3.9368	9.9995 9.9990	10.001 10.000
1970T	1970	250	850	HYATT * ‡	PULLEY	W224	"	8.4642 8.4670	4.7251 4.7266	3.8750	3.8750	21	.9375	4.7246 4.7241	11.750 11.749	11.752 11.750
		431	1150													
		656	1750		COMM	220	"	7.0863 7.0887	3.9376 3.9389	2.3125	2.3125	22	.750	3.9373 3.9368	9.9995 9.9990	10.001 10.000

* SEE TABLE A1 FOR A-B-C SKETCH OF ROLLER BEARING.

‡ THESE BEARINGS DO NOT CONFIRM TO S.A.E. SIZES

TABLE C-2

WESTINGHOUSE A.C. MOTORS

MOTOR DATA					BEARING DATA										
FRAME	TORQUE	H.P.	R.P.M	M'F'G.	S.A.E. BEARING SIZE		TYPE	A	B	C	D	BRG. HSG BORE	SHAFT DIA.	CART'G O.D.	BRACKET BORE
CS 232-F	13.7	3	1150		PULLEY	307	BALL	3.1496	1.3780	.8268	.8268	3.1497 3.1510	1.3785 1.3780	NON-CARTRIDGE	
	15	5	1750		O.E.	307	"	3.1496	1.3780	.8268	.8268	3.1497 3.1510	1.3785 1.3780	"	"
250-F	22.8	5	1150		PULLEY	308	"	3.5433	1.5748	.9055	.9055	3.5434 3.5447	1.5755 1.5750	"	"
	22.5	7½	1750		O.E.	307	"	3.1496	1.3780	.8268	.8268	3.1497 3.1510	1.3785 1.3780	"	"
342-F	342.5	7½	1150		PULLEY	310	"	4.3307	1.9685	1.0630	1.0630	4.3309 4.3322	1.9690 1.9685	"	"
					O.E.	310	"	4.3307	1.9685	1.0630	1.0630	4.3309 4.3322	1.9690 1.9685	"	"
343-F	30	10	1750		PULLEY	310	"	4.3307	1.9685	1.0630	1.0630	4.3309 4.3322	1.9690 1.9685	"	"
					O.E.	310	"	4.3307	1.9685	1.0630	1.0630	4.3309 4.3322	1.9690 1.9685	"	"
352-F	45.67	10	1150		PULLEY	310	"	4.3307	1.9685	1.0630	1.0630	4.3309 4.3322	1.9690 1.9685	"	"
					O.E.	310	"	4.3307	1.9685	1.0630	1.0630	4.3309 4.3322	1.9690 1.9685	"	"
361-F	45	15	1750		PULLEY	310	"	4.3307	1.9685	1.0630	1.0630	4.3309 4.3322	1.9690 1.9685	"	"
					O.E.	310	"	4.3307	1.9685	1.0630	1.0630	4.3309 4.3322	1.9690 1.9685	"	"
370-G	68.5	15	1150		PULLEY	311	"	4.7244	2.1654	1.1417	1.1417	4.7246 4.7259	2.1660 2.1655	"	"
					O.E.	310	"	4.3307	1.9685	1.0630	1.0630	4.3309 4.3322	1.9690 1.9685	"	"
371-G	60	20	1750		PULLEY	311	"	4.7244	2.1654	1.1417	1.1417	4.7246 4.7259	2.1660 2.1655	"	"
					O.E.	310	"	4.3307	1.9685	1.0630	1.0630	4.3309 4.3322	1.9690 1.9685	"	"
464-C	91.34	20	1150		PULLEY	313	"	5.5118	2.5591	1.2992	1.2992	5.5120 5.5133	2.5595 2.5590	"	"
					O.E.	311	"	4.7244	2.1654	1.1417	1.1417	4.7246 4.7259	2.1660 2.1655	"	"
473-C	75	25	1750		PULLEY	313	"	5.5118	2.5591	1.2992	1.2992	5.5120 5.5133	2.5595 2.5590	"	"
					O.E	311	"	4.7244	2.1654	1.1417	1.1417	4.7246 4.7259	2.1660 2.1655	"	"
481-C	90	30	1750		PULLEY	313	"	5.5118	2.5591	1.2992	1.2992	5.5120 5.5133	2.5595 2.5590	"	"
					O.E.	311	"	4.7244	2.1654	1.1417	1.1417	4.7246 4.7259	2.1660 2.1655	"	"
567-C	114.17	25	1150		PULLEY	315	"	6.2992	2.9528	1.4567	1.4567	6.2995 6.3010	2.9535 2.9530	"	"
	137.	30	1150		O.E.	311	"	4.7244	2.1654	1.1417	1.1417	4.7246 4.7259	2.1660 2.1655	"	"
583-C	120	40	1750		PULLEY	315	"	6.2992	2.9528	1.4567	1.4567	6.2995 6.3010	2.9535 2.9530	"	"
					O.E.	311	"	4.7244	2.1654	1.1417	1.1417	4.7246 4.7259	2.1660 2.1655	"	"
587-C	182.68	40	1150		PULLEY	315	"	6.2992	2.9528	1.4567	1.4567	6.2995 6.3010	2.9535 2.9530	"	"
	150	50	1750		O.E.	311	"	4.7244	2.1654	1.1417	1.1417	4.7246 4.7259	2.1660 2.1655	"	"
642-C	228.35	50	1150		PULLEY	319	"	7.8740	3.7402	1.7717	1.7717	7.8745 7.8762	3.7410 3.7405	9.8740 9.8730	9.8750 9.8770
					O.E.	315	"	6.2992	2.9528	1.4567	1.4567	6.2995 6.3010	2.9535 2.9530	8.2490 8.2480	8.2500 8.2520
662-C	274	60	1150		PULLEY	319	"	7.8740	3.7402	1.7717	1.7717	7.8745 7.8762	3.7410 3.7405	9.8740 9.8730	9.8750 9.8770
	342.5	75	1150		O.E.	315	"	6.2992	2.9528	1.4567	1.4567	6.2995 6.3010	2.9535 2.9530	8.2490 8.2480	8.2500 8.2520
752-C	456.7	100	1150		PULLEY	322	"	9.4488	4.3307	1.9685	1.9685	9.4493 9.4510	4.3315 4.3310	11.749 11.748	11.7500 11.7520
					O.E.	319	"	7.8740	3.7402	1.7717	1.7717	7.8745 7.8762	3.7410 3.7405	9.8740 9.8730	9.8750 9.8770
764-C	570.87	125	1150		PULLEY	322	"	9.4488	4.3307	1.9685	1.9685	9.4493 9.4510	4.3315 4.3310	11.7490 11.7480	11.7500 11.7520
					O.E.	319	"	7.8740	3.7402	1.7717	1.7717	7.8745 7.8762	3.7410 3.7405	9.8740 9.8730	9.8750 9.8770
772-C	685	150	1150		PULLEY	322	"	9.4488	4.3307	1.9685	1.9685	9.4493 9.4510	4.3315 4.3310	11.7490 11.7480	11.7500 11.7520
					O.E.	319	"	7.8740	3.7402	1.7717	1.7717	7.8745 7.8762	3.7410 3.7405	9.8740 9.8730	9.8750 9.8770
871-C	913.4	200	1150		PULLEY	5322	DOUBLE BALLS	9.4488	4.3307	3.6250	3.6250	9.4493 9.4510	4.3315 4.3310	11.7490 11.7480	11.7500 11.7520
					O.E.	319	BALL	7.8740	3.7402	1.7717	1.7717	7.8745 7.8762	3.7410 3.7405	9.8740 9.8730	9.8750 9.8770

60 CYCLE MOTORS

TABLE C-3

WESTINGHOUSE A.C. MOTORS

MOTOR DATA					BEARING DATA										
FRAME	TORQUE	H.P.	R.P.M.	M'F'G.	S.A.E. BEARING SIZE		TYPE	A	B	C	D	BRG. HSG. BORE	SHAFT DIA.	CART'G. O.D.	BRACKET BORE
CS 232F	14.7	2	715		PULLEY	307	BALL	3.1496	1.3780	.8268	.8268	3.1497 3.1510	1.3785 1.3780	NON-CARTRIDGE	
					O.E.	307	"	3.1496	1.3780	.8268	.8268	3.1497 3.1510	1.3785 1.3780	"	"
233F	7.24	2	1450		PULLEY	307	"	3.1496	1.3780	.8268	.8268	3.1497 3.1510	1.3785 1.3780	"	"
					O.E.	307	"	3.1496	1.3780	.8268	.8268	3.1497 3.1510	1.3785 1.3780	"	"
243F	10.86	3	1450		PULLEY	307	"	3.1496	1.3780	.8268	.8268	3.1497 3.1510	1.3785 1.3780	"	"
					O.E.	307	"	3.1496	1.3780	.8268	.8268	3.1497 3.1510	1.3785 1.3780	"	"
250F	22	3	715		PULLEY	308	"	3.5433	1.5748	.9055	.9055	3.5434 3.5447	1.5755 1.5750	"	"
					O.E.	307	"	3.1496	1.3780	.8268	.8268	3.1497 3.1510	1.3785 1.3780	"	"
343F	36.7	5	715		PULLEY	310	"	4.3307	1.9685	1.0630	1.0630	4.3309 4.3322	1.9690 1.9685	"	"
					O.E.	310	"	4.3307	1.9685	1.0630	1.0630	4.3309 4.3322	1.9690 1.9685	"	"
351.5F	18.1	5	1450		PULLEY	310	"	4.3307	1.9685	1.0630	1.0630	4.3309 4.3322	1.9690 1.9685	"	"
					O.E.	310	"	4.3307	1.9685	1.0630	1.0630	4.3309 4.3322	1.9690 1.9685	"	"
363.5F	27.16	7½	1450		PULLEY	310	"	4.3307	1.9685	1.0630	1.0630	4.3309 4.3322	1.9690 1.9685	"	"
					O.E.	310	"	4.3307	1.9685	1.0630	1.0630	4.3309 4.3322	1.9690 1.9685	"	"
461C	55.1	7½	715		PULLEY	313	"	5.5118	2.5591	1.2992	1.2992	5.5120 5.5133	2.5595 2.5590	"	"
461.5C	36.22	10	1450		O.E.	311	"	4.7244	2.1654	1.1417	1.1417	4.7246 4.7259	2.1660 2.1655	"	"
473C	73.4	10	715		PULLEY	313	"	5.5118	2.5591	1.2992	1.2992	5.5120 5.5133	2.5595 2.5590	"	"
473.5C	54.33	15	1450		O.E.	311	"	4.7244	2.1654	1.1417	1.1417	4.7246 4.7259	2.1660 2.1655	"	"
567C	110.1	15	715		PULLEY	315	"	6.2992	2.9528	1.4567	1.4567	6.2995 6.3010	2.9535 2.9530	"	"
					O.E.	311	"	4.7244	2.1654	1.1417	1.1417	4.7246 4.7259	2.1660 2.1655	"	"
583C	146.8	20	715		PULLEY	315	"	6.2992	2.9528	1.4567	1.4567	6.2995 6.3010	2.9535 2.9530	"	"
583.5C	72.44	20	1450												
583.5C	90.55	25	1450		O.E.	311	"	4.7244	2.1654	1.1417	1.1417	4.7246 4.7259	2.1660 2.1655	"	"
587.5C	108.66	30	1450		PULLEY	315	"	6.2992	2.9528	1.4567	1.4567	6.2995 6.3010	2.9535 2.9530	"	"
					O.E.	311	"	4.7244	2.1654	1.1417	1.1417	4.7246 4.7259	2.1660 2.1655	"	"
643C	183.5	25	715		PULLEY	319	"	7.8740	3.7402	1.7717	1.7717	7.8745 7.8762	3.7410 3.7405	9.8740 9.8730	9.8750 9.8770
	220.2	30	715		O.E.	315	"	6.2992	2.9528	1.4567	1.4567	6.2995 6.3010	2.9535 2.9530	8.2490 8.2480	8.2500 8.2520
645.5C	144.88	40	1450		PULLEY	319	"	7.8740	3.7402	1.7717	1.7717	7.8745 7.8762	3.7410 3.7405	9.8740 9.8730	9.8750 9.8770
					O.E.	315	"	6.2992	2.9402	1.4567	1.4567	6.2995 6.3010	2.9535 2.9530	8.2490 8.2480	8.2500 8.2520
663C	293.6	40	715		PULLEY	319	"	7.8740	3.7402	1.7717	1.7717	7.8745 7.8762	3.7410 3.7405	9.8740 9.8730	9.8750 9.8770
	367	50	715		O.E.	315	"	6.2992	2.9402	1.4567	1.4567	6.2995 6.3010	2.9535 2.9530	8.2490 8.2480	8.2500 8.2520
655.5C	181.1	50	1450		PULLEY	319	"	7.8740	3.7402	1.7717	1.7717	7.8745 7.8762	3.7410 3.7405	9.8740 9.8730	9.8750 9.8770
					O.E	315	"	6.2992	2.9402	1.4567	1.4567	6.2995 6.3010	2.9535 2.9530	8.2490 8.2480	8.2500 8.2520
751.5C	217.32	60	1450		PULLEY	322	"	9.4488	4.3307	1.9685	1.9685	9.4493 9.4510	4.3315 4.3310	11.7490 11.7480	11.7500 11.7520
	271.6	75	1450		O.E.	319	"	7.8740	3.7402	1.7717	1.7717	7.8745 7.8762	3.7410 3.7405	9.8740 9.8730	9.8750 9.8770
761C	440.4	60	715		PULLEY	322	"	9.4488	4.3307	1.9685	1.9685	9.4493 9.4510	4.3315 4.3310	11.7490 11.7480	11.7500 11.7520
	550.5	75	715		O.E.	319	"	7.8740	3.7402	1.7717	1.7717	7.8745 7.8762	3.7410 3.7405	9.8740 9.8730	9.8750 9.8770
771.5C	362.2	100	1450		PULLEY	322	"	9.4488	4.3307	1.9685	1.9685	9.4493 9.4510	4.3315 4.3310	11.7490 11.7480	11.7500 11.7520
					O.E.	319	"	7.8740	3.7402	1.7717	1.7717	7.8745 7.8762	3.7410 3.7405	9.8740 9.8730	9.8750 9.8770
855C	734	100	715		PULLEY	5322	DOUBLE BALL	9.4488	4.3307	3.6250	3.6250	9.4493 9.4510	4.3315 4.3310	11.7490 11.7480	11.7500 11.7520
					O.E.	319	BALL	7.8740	3.7402	1.7717	1.7717	7.8745 7.8762	3.7410 3.7405	9.8740 9.8730	9.8750 9.8770
871.5ZC	452.75	125	1450		PULLEY	5322	DOUBLE BALL	9.4488	4.3307	3.6250	3.6250	9.4493 9.4510	4.3315 4.3310	11.7490 11.7480	11.7500 11.7520
871.5C	543.3	150	1450		O.E.	319	BALL	7.8740	3.7402	1.7717	1.7717	7.8745 7.8762	3.7410 3.7405	9.8740 9.8730	9.8750 9.8770
877C	917.5	125	715		PULLEY	5322	DOUBLE BALL	9.4488	4.3307	3.6250	3.6250	9.4493 9.4510	4.3315 4.3310	11.7490 11.7480	11.7500 11.7520
	1101	150	450		O.E.	319	BALL	7.8740	3.7402	1.7717	1.7717	7.8745 7.8762	3.7410 3.7405	9.8740 9.8730	9.8750 9.8770

25 CYCLE MOTORS

TABLE-C3a

WESTINGHOUSE D.C. MOTORS

MOTOR DATA					BEARING DATA										
FRAME	TORQUE	H.P.	R.P.M.	M'F'G.	S.A.E. BEARING SIZE		TYPE	A	B	C	D	BRG. HSG BORE	SHAFT DIA.	CART'G O.D.	BRACKET BORE
SK 23	13.7	3	1150		PULLEY	308	BALL	3.5433	1.5748	.9055	.9055	3.5434 3.5447	1.5755 1.5750	NON-CARTRIDGE	
	15	5	1750		COMM	307	"	3.1496	1.3780	.8268	.8268	3.1497 3.1510	1.3785 1.3780	"	"
33	22.8	5	1150		PULLEY	310	"	4.3307	1.9685	1.0630	1.0630	4.3309 4.3322	1.9690 1.9685	"	"
	22.5	7½	1750		COMM	307	"	3.1496	1.3780	.8268	.8268	3.1497 3.1510	1.3785 1.3780	"	"
43	34.25	7½	1150		PULLEY	310	"	4.3307	1.9685	1.0630	1.0630	4.3309 4.3322	1.9690 1.9685	"	"
	30	10	1750		COMM	307	"	3.1496	1.3780	.8268	.8268	3.1497 3.1510	1.3785 1.3780	"	"
63	45.67	10	1150		PULLEY	311	"	4.7244	2.1654	1.1417	1.1417	4.7246 4.7259	2.1660 2.1655	"	"
	45	15	1750		COMM	308	"	3.5433	1.5748	.9055	.9055	3.5434 3.5447	1.5755 1.5750	"	"
83	68.5	15	1150		PULLEY	313	"	5.5118	2.5591	1.2992	1.2991	5.5120 5.5133	2.5595 2.5590	"	"
	60	20	1750		COMM	311	"	4.7244	2.1654	1.1417	1.1417	4.7246 4.7259	2.1660 2.1655	"	"
	75	25	1750												
93	91.34	20	1150		PULLEY	313	"	5.5118	2.5591	1.2992	1.2991	5.5120 5.5133	2.5595 2.5590	"	"
	90	30	1750		COMM	311	"	4.7244	2.1654	1.1417	1.1417	4.7246 4.7259	2.1660 2.1655	"	"
10	114.17	25	1150		PULLEY	315	"	6.2992	2.9528	1.4567	1.4567	6.2995 6.3010	2.9535 2.9530	"	"
	120	40	1750		COMM	311	"	4.7244	2.1654	1.1417	1.1417	4.7246 4.7259	2.1660 2.1655	"	"
113	137	30	1150		PULLEY	315	"	6.2992	2.9528	1.4567	1.4567	6.2995 6.3010	2.9535 2.9530	"	"
	150	50	1750		COMM	311	"	4.7244	2.1654	1.1417	1.1417	4.7246 4.7259	2.1660 2.1655	"	"
123	182.68	40	1150		PULLEY	315	"	6.2992	2.9528	1.4567	1.4567	6.2995 6.3010	2.9535 2.9530	"	"
					COMM	311	"	4.7244	2.1654	1.1417	1.1417	4.7246 4.7259	2.1660 2.1655	"	"
133	228.35	50	1150		PULLEY	319	"	7.8740	3.7402	1.7717	1.7717	7.8745 7.8762	3.7410 3.7405	9.8740 9.8730	9.8750 9.8770
					COMM	315	"	6.2992	2.9528	1.4567	1.4567	6.2995 6.3010	2.9535 2.9530	8.2490 8.2480	8.2500 8.2520
143-L	274	60	1150		PULLEY	319	"	7.8740	3.7402	1.7717	1.7717	7.8745 7.8762	3.7410 3.7405	9.8740 9.8730	9.8750 9.8770
					COMM	315	"	6.2992	2.9528	1.4567	1.4567	6.2995 6.3010	2.9535 2.9530	8.2490 8.2480	8.2500 8.2520
153	342.5	75	1150		PULLEY	319	"	7.8740	3.7402	1.7717	1.7717	7.8745 7.8762	3.7410 3.7405	9.8740 9.8730	9.8750 9.8770
					COMM	315	"	6.2992	2.9528	1.4567	1.4567	6.2995 6.3010	2.9535 2.9530	8.2490 8.2480	8.2500 8.2520
163	456.7	100	1150		PULLEY	322	"	9.4488	4.3307	1.9685	1.9685	9.4493 9.4510	4.3315 4.3310	11.7490 11.7480	11.7500 11.7520
					COMM	319	"	7.8740	3.7402	1.7717	1.7717	7.8745 7.8762	3.7410 3.7405	9.8740 9.8730	9.8750 9.8770
173	570.87	125	1150		PULLEY	322	"	9.4488	4.3307	1.9685	1.9685	9.4493 9.4510	4.3315 4.3310	11.7490 11.7480	11.7500 11.7520
					COMM	319	"	7.8740	3.7402	1.7717	1.7717	7.8745 7.8762	3.7410 3.7405	9.8740 9.8730	9.8750 9.8770
183-A	685	150	1150		PULLEY	5322	DOUBLE BALLS	9.4488	4.3307	3.6250	3.6250	9.4493 9.4510	4.3315 4.3310	11.7490 11.7480	11.7500 11.7520
					COMM	319	BALL	7.8740	3.7402	1.7717	1.7717	7.8745 7.8762	3.7410 3.7405	9.8740 9.8730	9.8750 9.8770
184-B	913.4	200	1150		PULLEY	5322	DOUBLE BALLS	9.4488	4.3307	3.6250	3.6250	9.4493 9.4510	4.3315 4.3310	11.7490 11.7480	11.7500 11.7520
					COMM	319	BALL	7.8740	3.7402	1.7717	1.7717	7.8745 7.8762	3.7410 3.7405	9.8740 9.8730	9.8750 9.8770

FRAME *53SK USED ON SOME STANDARD ADJUSTABLE SPEED RATINGS HAS THE SAME BEARINGS AS LISTED FOR FRAME *63SK.

TABLE C-4

GENERAL ELECTRIC A.C. MOTORS

MOTOR DATA				BEARING DATA												
FRAME	TORQUE	H.P.	R.P.M	M'F'G.	S.A.E. BEARING SIZE	TYPE	A	B	C	D	BALLS Nº	BALLS DIA.	SHAFT DIA.	CART'G. O.D.	SHIELD BORE
K.T. 503Y	54	15	1500		PULLEY 312	BALL	5.1181	2.3622	1.2205	1.2205			2.3626 2.3621		5.1194 5.1183
					O.E. 312	"	5.1181	2.3622	1.2205	1.2205			2.3626 2.3621		5.1194 5.1183
512	72	10	750		PULLEY 313	"	5.5118	2.5591	1.2992	1.2992			2.5595 2.5590		5.5131 5.5120
					O.E. 309	"	3.9370	1.7717	.9843	.9843			1.7722 1.7717		3.9380 3.9369
513Y	72	20	1500		PULLEY 313	"	5.5118	2.5591	1.2992	1.2992			2.5595 2.5590		5.5131 5.5120
					O.E. 313	"	5.5118	2.5591	1.2992	1.2992			2.5595 2.5590		5.5131 5.5120
522	110	10	500		PULLEY 315	"	6.2992	2.9528	1.4567	1.4567			2.9532 2.9527		6.3008 6.2995
					O.E. 312	"	5.1181	2.3622	1.2205	1.2205			2.3626 2.3621		5.1194 5.1183
523	110	15	750		PULLEY 315	"	6.2992	2.9528	1.4567	1.4567			2.9532 2.9527		6.3008 6.2995
	90	25	1500		O.E. 312	"	5.1181	2.3622	1.2205	1.2205			2.3626 2.3621		5.1194 5.1183
527	145	20	750		PULLEY 315	"	6.2992	2.9528	1.4567	1.4567			2.9532 2.9527		6.3008 6.2995
	108	30	1500		O.E. 312	"	5.1181	2.3622	1.2205	1.2205			2.3626 2.3621		5.1194 5.1183
532	165	15	500		PULLEY 318	"	7.4803	3.5433	1.6929	1.6929			3.5436 3.5431		7.4820 7.4807
					O.E. 315	"	6.2992	2.9528	1.4567	1.4567			2.9532 2.9527		6.3008 6.2995
533	180	25	750		PULLEY 318	"	7.4803	3.5433	1.6929	1.6929			3.5436 3.5431		7.4820 7.4807
	145	40	1500		O.E 315	"	6.2992	2.9528	1.4567	1.4567			2.9532 2.9527		6.3008 6.2995
536	220	20	500		PULLEY 318	"	7.4803	3.5433	1.6929	1.6929			3.5436 3.5431		7.4820 7.4807
					O.E. 315	"	6.2992	2.9528	1.4567	1.4567			2.9532 2.9527		6.3008 6.2995
537	215	30	750		PULLEY 318	"	7.4803	3.5433	1.6929	1.6929			3.5436 3.5431		7.4820 7.4807
	180	50	1500		O.E. 315	"	6.2992	2.9528	1.4567	1.4567			2.9532 2.9527		6.3008 6.2995
539	215	60	1500		PULLEY 318	"	7.4803	3.5433	1.6929	1.6929			3.5436 3.5431		7.4820 7.4807
					O.E. 315	"	6.2992	2.9528	1.4567	1.4567			2.9532 2.9527		6.3008 6.2995
543	270	25	500		PULLEY 319	"	7.8740	3.7402	1.7717	1.7717			3.7405 3.7399		7.8761 7.8746
	285	40	750		O.E. 315	"	6.2992	2.9528	1.4567	1.4567			2.9532 2.9527		6.3008 6.2995
	270	75	1500												
547	325	30	500		PULLEY 319	"	7.8740	3.7402	1.7717	1.7717			3.7405 3.7399		7.8761 7.8746
	360	50	750		O.E. 315	"	6.2992	2.9528	1.4567	1.4567			2.9532 2.9527		6.3008 6.2995
549	362	100	500		PULLEY 319	"	7.8740	3.7402	1.7717	1.7717			3.7405 3.7399		7.8761 7.8746
	435	125	1500		O.E 315	"	6.2992	2.9528	1.4567	1.4567			2.9532 2.9527		6.3008 6.2995
553	435	40	500		PULLEY 319	"	7.8740	3.7402	1.7717	1.7717			3.7405 3.7399		7.8761 7.8746
	435	60	750		O.E. 319	"	7.8740	3.7402	1.7717	1.7717			3.7405 3.7399		7.8761 7.8746
557	540	50	500		PULLEY	ROLLER	9.4488	4.3307	3.7500	3.7500			4.3327 4.3313		9.4509 9.4494
	655	60	500												
	545	75	750		O.E. 319	BALL	7.8740	3.7402	1.7717	1.7717			3.7405 3.7399		7.8761 7.8746
	525	150	1500												
559	810	75	500		PULLEY	ROLLER	9.4488	4.3307	3.7500	3.7500			4.3327 4.3313		9.4509 9.4494
	720	100	750		O.E. 319	BALL	7.8740	3.7402	1.7717	1.7717			3.7405 3.7399		7.8761 7.8746
	682	200	1500												
561	904	125	750		PULLEY	ROLLER	10.2362	4.7244	4.1250	4.1250			4.7255 4.7247		10.2376 10.2366
					O.E. 322	BALL	9.4488	4.3307	1.9685	1.9685			4.3310 4.3304		9.4509 9.4494
563	1080	100	500		PULLEY	ROLLER	11.0236	5.1181	4.3750	4.3750			5.1192 5.1184		11.0250 11.0240
	1365	125	500		O.E. 322	BALL	9.4488	4.3307	1.9685	1.9685			4.3310 4.3304		9.4509 9.4494
	1080	150	750												
565	1622	150	500		PULLEY	ROLLER	11.0236	5.1181	4.3750	4.3750			5.1192 5.1184		11.0250 11.0240
	1440	200	750		O.E. 322	BALL	9.4488	4.3307	1.9685	1.9685			4.3310 4.3304		9.4509 9.4494

25 CYCLE MOTORS

TABLE C-5

General Electric A.C. Motors

Motor Data					Bearing Data											
Frame	Torque	H.P.	R.P.M.	M'f'G.	S.A.E. Bearing Size		Type	A	B	C	D	Balls Nº	Balls Dia.	Shaft Dia.	Cart'g O.D	Shield Bore
K.T 916	3.83	½	750		Pulley	305	Ball	2.4409	.9843	.6693	.6693		.375	.9843 .9840	3.249 3.248	3.2510 3.2500
					O.E.	305	"	2.4409	.9843	.6693	.6693		.375	.9843 .9840	3.249 3.248	3.2510 3.2500
926	7.5	1	750		Pulley	306	"	2.8346	1.1811	.7480	.7480		.437	1.1811 1.1808	3.624 3.623	3.6260 3.6250
	3.66	1	1500		O.E.	306	"	2.8346	1.1811	.7480	.7480		.437	1.1811 1.1808	3.624 3.623	3.6260 3.6250
932	11.3	1½	750		Pulley	307	"	3.1496	1.3780	.8268	.8268		.500	1.3780 1.3777	4.124 4.123	4.1260 4.1250
					O.E.	307	"	3.1496	1.3780	.8268	.8268		.500	1.3780 1.3777	4.124 4.123	4.1260 4.1250
934	7.25	2	1500		Pulley	307	"	3.1496	1.3780	.8268	.8268		.500	1.3780 1.3777	4.124 4.123	4.1260 4.1250
					O.E.	307	"	3.1496	1.3780	.8268	.8268		.500	1.3780 1.3777	4.124 4.123	4.1260 4.1250
936	14.8	2	750		Pulley	307	"	3.1496	1.3780	.8268	.8268		.500	1.3780 1.3777	4.124 4.123	4.1260 4.1250
					O.E.	307	"	3.1496	1.3780	.8268	.8268		.500	1.3780 1.3777	4.124 4.123	4.1260 4.1250
944	22	3	750		Pulley	309	"	3.9370	1.7717	.9843	.9843		.625	1.7717 1.7714	4.998 4.997	5.0010 5.0000
	10.9	3	1500		O.E.	309	"	3.9370	1.7717	.9843	.9843		.625	1.7717 1.7714	4.998 4.997	5.0010 5.0000
948	37	5	750		Pulley	309	"	3.9370	1.7717	.9843	.9843		.625	1.7717 1.7714	4.998 4.997	5.0010 5.0000
	18.3	5	1500		O.E.	309	"	3.9370	1.7717	.9843	.9843		.625	1.7717 1.7714	4.998 4.997	5.0010 5.0000
954	54.5	7½	750		Pulley	310	"	4.3307	1.9685	1.0630	1.0630		.687	1.9685 1.9682	5.498 5.497	5.5010 5.5000
	27.5	7½	1500		O.E.	310	"	4.3307	1.9685	1.0630	1.0630		.687	1.9685 1.9682	5.498 5.497	5.5010 5.5000
958	36.4	10	1500		Pulley	310	"	4.3307	1.9685	1.0630	1.0630		.687	1.9685 1.9682	5.498 5.497	5.5010 5.5000
					O.E.	310	"	4.3307	1.9685	1.0630	1.0630		.687	1.9685 1.9682	5.498 5.497	5.5010 5.5000

25 Cycle Motors

Table C-6

General Electric A.C. Motors

Motor Data				Bearing Data											
Frame	Torque	H.P.	R.P.M	Mf'g.	S.A.E. Bearing Size		Type	A	B	C	D	Balls No.	Balls Dia.	Shaft Dia.	Cart'g O.D.	Shield Bore
K.T. 914	6.2	¾	1800		Pulley	305	Ball	2.4409	.9843	.6693	.6693		.375	.9843 .9840	3.249 3.248	3.251 3.250
					O.E.	305	"	2.4409	.9843	.6693	.6693		.375	.9843 .9840	3.249 3.248	3.251 3.250
916	7.0	¾	1200		Pulley	305	"	2.4409	.9843	.6693	.6693		.375	.9843 .9840	3.249 3.248	3.251 3.250
	8.7	1	1800		O.E.	305	"	2.4409	.9843	.6693	6693		.375	.9843 .9840	3.249 3.248	3.251 3.250
924	9.4	1	1200		Pulley	306	"	2.8346	1.1811	.7480	.7480		.437	1.1811 1.1808	3.624 3.623	3.626 3.625
	13.5	1½	1800		O.E.	306	"	2.8346	1.1811	.7480	.7480		.437	1.1811 1.1808	3.624 3.623	3.626 3.625
926	11.0	¾	900		Pulley	306	"	2.8346	1.1811	.7480	.7480		.437	1.1811 1.1808	3.624 3.623	3.626 3.625
	14.3	1½	1200													
	18.0	2	1800		O.E.	306	"	2.8346	1.1811	.7480	.7480		.437	1.1811 1.1808	3.624 3.623	3.626 3.625
932	14.0	1	900		Pulley	307	"	3.1496	1.3780	.8268	.8268		.500	1.3780 1.3777	4.124 4.123	4.126 4.125
	25.0	1½	900													
	25.0	3	1800		O.E.	307	"	3.1496	1.3780	.8268	.8268		.500	1.3780 1.3777	4.124 4.123	4.126 4.125
934	19.0	2	1200		Pulley	307	"	3.1496	1.3780	.8268	.8268		.500	1.3780 1.3777	4.124 4.123	4.126 4.125
					O.E.	307	"	3.1496	1.3780	.8268	.8268		.500	1.3780 1.3777	4.124 4.123	4.126 4.125
936	39.0	2	900		Pulley	307	"	3.1496	1.3780	.8268	.8268		500	1.3780 1.3777	4.124 4.123	4.126 4.125
	45.0	5	1800		O.E.	307	"	3.1496	1.3780	.8268	.8268		.500	1.3780 1.3777	4.124 4.123	4.126 4.125
938	29.0	3	1200		Pulley	307	"	3.1496	1.3780	.8268	.8268		.500	1.3780 1.3777	4.124 4.123	4.126 4.125
					O.E.	307	"	3.1496	1.3780	.8268	.8268		.500	1.3780 1.3777	4.124 4.123	4.126 4.125
944	44.0	3	900		Pulley	309	"	3.9370	1.7717	.9843	.9843		.625	1.7717 1.7714	4.998 4.997	5.001 5.000
	62.0	7½	1800		O.E.	309	"	3.9370	1.7717	.9843	.9843		.625	1.7717 1.7714	4.998 4.997	5.001 5.000
946	48.0	5	1200		Pulley	309	"	3.9370	1.7717	.9843	.9843		.625	1.7717 1.7714	4.998 4.997	5.001 5.000
					O.E.	309	"	3.9370	1.7717	.9843	.9843		.625	1.7717 1.7714	4.998 4.997	5.001 5.000
948	82.0	10	1800		Pulley	309	"	3.9370	1.7717	.9843	.9843		.625	1.7717 1.7714	4.998 4.997	5.001 5.000
					O.E.	309	"	3.9370	1.7717	.9843	.9843		.625	1.7717 1.7714	4.998 4.997	5.001 5.000
952	70.0	5	900		Pulley	310	"	4.3307	1.9685	1.0630	1.0630		.687	1.7717 1.7714	4.998 4.997	5.001 5.000
	75.0	7½	1200		O.E.	310	"	4.3307	1.9685	1.0630	1.0630		.687	1.7717 1.7714	4.998 4.997	5.001 5.000
954	147.0	15	1800		Pulley	310	"	4.3307	1.9685	1.0630	1.0630		.687	1.7717 1.7714	4.998 4.997	5.001 5.000
					O.E.	310	"	4.3307	1.9685	1.0630	1.0630		.687	1.7717 1.7714	4.998 4.997	5.001 5.000
956	96.0	10	1200		Pulley	310	"	4.3307	1.9685	1.0630	1.0630		.687	1.7717 1.7714	4.998 4.997	5.001 5.000
					O.E.	310	"	4.3307	1.9685	1.0630	1.0630		.687	1.7717 1.7714	4.998 4.997	5.001 5.000
958	95.0	7½	900		Pulley	310	"	4.3307	1.9685	1.0630	1.0630		.687	1.7717 1.7714	4.998 4.997	5.001 5.000
					O.E.	310	"	4.3307	1.9685	1.0630	1.0630		.687	1.7717 1.7714	4.998 4.997	5.001 5.000

60 Cycle Motors

Table C-6a

GENERAL ELECTRIC A.C. MOTORS

MOTOR DATA				BEARING DATA												
FRAME	TORQUE	H.P.	R.P.M.	MFG.	S.A.E. BEARING SIZE	TYPE	A	B	C	D	BALLS Nº	BALLS DIA.	SHAFT DIA.	CART'G O.D.	SHIELD BORE
K.T. 502	67	15	1200		PULLEY 312	BALL	5.1181	2.3622	1.2205	1.2205		.8125	2.3626 2.3621		5.1194 5.1183
	60	10	900		O.E. 309	"	3.9370	1.7717	.9843	.9843		.625	1.7722 1.7717		3.9383 3.9372
512	89	20	1200		PULLEY 313	"	5.5118	2.5591	1.2992	1.2992		.875	2.5595 2.5590		5.5131 5.5120
	90	15	900		O.E. 309	"	3.9370	1.7717	.9843	.9843		.625	1.7722 1.7717		3.9383 3.9372
522	112	25	1200		PULLEY 315	"	6.2992	2.9528	1.4567	1.4567		1.00	2.9532 2.9527		6.3008 6.2995
	121	20	900		O.E. 312	"	5.1181	2.3622	1.2205	1.2205		.8125	2.3626 2.3621		5.1194 5.1183
526	135	30	1200		PULLEY 315	"	6.2992	2.9528	1.4567	1.4567		1.00	2.9532 2.9527		6.3008 6.2995
	152	25	900		O.E. 312	"	5.1181	2.3622	1.2205	1.2205		.8125	2.3626 2.3621		5.1194 5.1183
532	183	40	1200		PULLEY 318	"	7.4803	3.5433	1.6929	1.6929		1.1875	3.5436 3.5431		7.4820 7.4807
	183	30	900		O.E. 315	"	6.2992	2.9528	1.4567	1.4567		1.00	2.9532 2.9527		6.3008 6.2995
536	269	60	1200		PULLEY 318	"	7.4803	3.5433	1.6929	1.6929		1.1875	3.5436 3.5431		7.4820 7.4807
	247	40	900		O.E. 315	"	6.2992	2.9528	1.4567	1.4567		1.00	2.9532 2.9527		6.3008 6.2995
542	303	50	900		PULLEY 319	"	7.8740	3.7402	1.7717	1.7717		1.25	3.7405 3.7399		7.8761 7.8746
	307	40	720		O.E. 315	"	6.2992	2.9528	1.4567	1.4567		1.00	2.9532 2.9527		6.3008 6.2995
546	362	60	900		PULLEY 319	"	7.8740	3.7402	1.7717	1.7717		1.25	3.7405 3.7399		7.8761 7.8746
	382	50	720		O.E. 315	"	6.2992	2.9528	1.4567	1.4567		1.00	2.9532 2.9527		6.3008 6.2995
552	452	75	900		PULLEY 319	"	7.8740	3.7402	1.7717	1.7717		1.25	3.7405 3.7399		7.8761 7.8746
	450	60	720		O.E. 319	"	7.8740	3.7402	1.7717	1.7717		1.25	3.7405 3.7399		7.8761 7.8746
556	600	100	900		PULLEY	ROLLER	9.4488	4.3307	3.7500	3.7500			4.3327 4.3313		9.4509 9.4494
	547	60	600		O.E. 319	BALL	7.8740	3.7402	1.7717	1.7717		1.25	3.7405 3.7399		7.8761 7.8746
558	750	125	900		PULLEY	ROLLER	9.4488	4.3307	3.7500	3.7500			4.3327 4.3313		9.4509 9.4494
	678	75	600		O.E. 319	BALL	7.8740	3.7402	1.7717	1.7717		1.25	3.7405 3.7399		7.8761 7.8746
562	945	125	720		PULLEY	ROLLER	10.2362	4.7244	4.1250	4.1250			4.7255 4.7247		10.2376 10.2366
	1140	125	600		O.E. 322	BALL	9.4488	4.3307	1.9685	1.9685		1.50	4.3310 4.3304		9.4509 9.4494
564	1140	150	720		PULLEY	ROLLER	11.0236	5.1181	4.3750	4.3750			5.1192 5.1184		11.0250 11.0240
	1370	150	600		O.E. 322	BALL	9.4488	4.3307	1.9685	1.9685		1.50	4.3310 4.3304		9.4509 9.4494
966	1810	200	600		PULLEY	ROLLER	11.0236	5.1181	4.3750	4.3750			5.1192 5.1184		11.0250 11.0240
					O.E. 322	BALL	9.4488	4.3307	1.9685	1.9685		1.50	4.3310 4.3304		9.4509 9.4494

60 CYCLE MOTORS

SEE TABLE A1 FOR A-B-C SKETCH OF ROLLER BEARING

TABLE C-6b

GENERAL ELECTRIC A.C. MOTORS

MOTOR DATA					BEARING DATA											
FRAME	TORQUE	H.P.	R.P.M.	M'F'G.	S.A.E. BEARING SIZE		TYPE	A	B	C	D	BALLS Nº	BALLS DIA.	SHAFT DIA.	CART'G O.D.	SHIELD BORE
MT 926	5.7	¾	750		PULLEY	306	BALL	2.8346	1.1811	.7480	.7480			1.1811 1.1808	3.6240 3.6230	3.6260 3.6250
					O.E.	305	"	2.4410	.9843	.6693	.6693			.9843 .9840	3.2490 3.2480	3.2510 3.2500
932	7.6	1	750		PULLEY	307	"	3.1496	1.3780	.8268	.8268			1.3780 1.3777	4.1240 4.1230	4.1260 4.1250
					O.E.	306	"	2.8346	1.1811	.7480	.7480			1.1811 1.1808	3.6240 3.6230	3.6260 3.6250
936	11.4	1½	750		PULLEY	307	"	3.1496	1.3780	.8268	.8268			1.3780 1.3777	4.1240 4.1230	4.1260 4.1250
					O.E.	306	"	2.8346	1.1811	.7480	.7480			1.1811 1.1808	3.6240 3.6230	3.6260 3.6250
944	14.9	2	750		PULLEY	309	"	3.9370	1.7717	.9843	.9843			1.7717 1.7714	4.9980 4.9970	5.0010 5.0000
					O.E.	307	"	3.1496	1.3780	.8268	.8268			1.3780 1.3777	4.1240 4.1230	4.1260 4.1250
948	22.2	3	750		PULLEY	309	"	3.9370	1.7717	.9843	.9843			1.7717 1.7714	4.9980 4.9970	5.0010 5.0000
					O.E.	307	"	3.1496	1.3780	.8268	.8268			1.3780 1.3777	4.1240 4.1230	4.1260 4.1250
954	36.7	5	750		PULLEY	310	"	4.3307	1.9685	1.0630	1.0630			1.9685 1.9682	5.4980 5.4970	5.5010 5.5000
					O.E.	309	"	3.9370	1.7717	.9843	.9843			1.7717 1.7714	4.9980 4.9970	5.0010 5.0000
503	56	7½	750		PULLEY	312	"	5.1181	2.3622	1.2205	1.2205			2.3626 2.3621	NONE	5.1194 5.1183
					PULLEY	313	"	5.5118	2.5591	1.2992	1.2992			2.5595 2.5590	"	5.5131 5.5126
513	75	10	750		O.E.	309	"	3.9370	1.7717	.9843	.9843			1.7722 1.7717	"	3.9383 3.9372
523	111	15	750		PULLEY	315	"	6.2992	2.9528	1.4567	1.4567			2.9532 2.9527	"	6.3008 6.2995
					O.E	312	"	5.1181	2.3622	1.2205	1.2205			2.3626 2.3621	"	5.1194 5.1183
526	105	10	500		PULLEY	315	"	6.2992	2.9528	1.4567	1.4567			2.9532 2.9527	"	6.3008 6.2995
					O.E.	312	"	5.1181	2.3622	1.2205	1.2205			2.3626 2.3621	"	5.1194 5.1183
527	151.1	20	750		PULLEY	315	"	6.2992	2.9528	1.4567	1.4567			2.9532 2.9527	"	6.3008 6.2995
					O.E.	312	"	5.1181	2.3622	1.2205	1.2205			2.3626 2.3621	"	5.1194 5.1183
532	110	15	500		PULLEY	318	"	7.4803	3.5433	1.6929	1.6929			3.5436 3.5431	"	7.4820 7.4807
					O.E.	315	"	6.2992	2.9528	1.4567	1.4567			2.9532 2.9527	"	6.3008 6.2995
533	190	25	750		PULLEY	318	"	7.4803	3.5433	1.6929	1.6929			3.5436 3.5431	"	7.4820 7.4807
					O.E.	315	"	6.2992	2.9528	1.4567	1.4567			2.9532 2.9527	"	6.3008 6.2995
536	226	20	500		PULLEY	318	"	7.4803	3.5433	1.6929	1.6929			3.5436 3.5431	"	7.4820 7.4807
					O.E.	315	"	6.2992	2.9528	1.4567	1.4567			2.9532 2.9527	"	6.3008 6.2995
537	225	30	750		PULLEY	318	"	7.4803	3.5433	1.6929	1.6929			3.5436 3.5431	"	7.4820 7.4807
					O.E.	315	"	6.2992	2.9528	1.4567	1.4567			2.9532 2.9527	"	6.3008 6.2995
543	279	25	500		PULLEY	319	"	7.8740	3.7402	1.7717	1.7717			3.7405 3.7399	"	7.8761 7.8746
	298	40	750		O.E.	315	"	6.2992	2.9528	1.4567	1.4567			2.9532 2.9527	"	6.3008 6.2995
547	331	30	500		PULLEY	319	"	7.8740	3.7402	1.7717	1.7717			3.7405 3.7399	"	7.8761 7.8746
	367	50	750		O.E.	315	"	6.2992	2.9528	1.4567	1.4567			2.9532 2.9527	"	6.3008 6.2995
553	447	40	500		PULLEY	319	"	7.8740	3.7402	1.7717	1.7717			3.7405 3.7399	"	7.8761 7.8746
	443	60	750		O.E.	319	"	7.8740	3.7402	1.7717	1.7717			3.7405 3.7399	"	7.8761 7.8746
557	552	50	500		PULLEY		ROLLER	9.4488	4.3307	3.7500	3.7500			4.3327 4.3313	"	9.4509 9.4494
	551	75	750		O.E.	319	BALL	7.8740	3.7402	1.7717	1.7717			3.7405 3.7399	"	7.8761 7.8746
559	656	60	500		PULLEY		ROLLER	9.4488	4.3307	3.7500	3.7500			4.3327 4.3313	"	9.4509 9.4494
	829	75	500		O.E.	319	BALL	7.8740	3.7402	1.7717	1.7717			3.7405 3.7399	"	7.8761 7.8746
	729	100	750													
561	1104	100	500		PULLEY		ROLLER	10.2362	4.7244	4.1250	4.1250			4.7255 4.7247	"	10.2376 10.2366
	917	125	750		O.E.	322	BALL	9.4488	4.3307	1.9685	1.9685			4.3310 4.3304	"	9.4509 9.4494
563	1380	125	500		PULLEY		ROLLER	11.0236	5.1181	4.3750	4.3750			5.1192 5.1184	"	11.0250 11.0240
	1096	150	750		O.E.	322	BALL	9.4488	4.3307	1.9685	1.9685			4.3310 4.3304	"	9.4509 9.4494
565	1640	150	500		PULLEY		ROLLER	11.0236	5.1181	4.3750	4.3750			5.1192 5.1184	"	11.0250 11.0240
					O.E.	322	BALL	9.4488	4.3307	1.9685	1.9685			4.3310 4.3304	"	9.4509 9.4494

25 CYCLE MOTORS

TABLE C-7

GENERAL ELECTRIC A.C. MOTORS

MOTOR DATA				BEARING DATA											
FRAME	TORQUE	H.P.	R.P.M	M'F'G.	S.A.E. BEARING SIZE	TYPE	A	B	C	D	BALLS Nº	BALLS DIA.	SHAFT DIA.	CART'G O.D.	SHIELD BORE
M.T. 926	9.2	1	1200		PULLEY	306	BALL	2.8346	1.1811	.7480	.7480		.437	1.1811 1.1808	3.624 3.623	3.626 3.625
	20	2	1800		O.E.	305	"	2.4410	.9843	.6693	.6693		.6693	.9843 .9840	3.249 3.248	3.251 3.250
932	22	3	1800		PULLEY	307	"	3.1496	1.3780	.8268	.8268		.500	1.3780 1.3777	4.124 4.123	4.126 4.125
					O.E.	306	"	2.8346	1.1811	.7480	.7480		.7480	1.1811 1.1808	3.624 3.623	3.626 3.625
934	19	2	1200		PULLEY	307	"	3.1496	1.3780	.8268	.8268		.500	1.3780 1.3777	4.124 4.123	4.126 4.125
					O.E.	306	"	2.8346	1.1811	.7480	.7480		.437	1.1811 1.1808	3.624 3.623	3.626 3.625
936	31.3	2	900		PULLEY	307	"	3.1496	1.3780	.8268	.8268		.500	1.3780 1.3777	4.124 4.123	4.126 4.125
	33	5	1800		O.E.	306	"	2.8346	1.1811	.7480	.7480		.437	1.1811 1.1808	3.624 3.623	3.626 3.625
938	28	3	1200		PULLEY	307	"	3.1496	1.3780	.8268	.8268		.500	1.3780 1.3777	4.124 4.123	4.126 4.125
					O.E.	306	"	2.8346	1.1811	.7480	.7480		.437	1.1811 1.1808	3.624 3.623	3.626 3.625
944	40.7	3	900		PULLEY	309	"	3.9370	1.7717	.9843	.9843		.625	1.7717 1.7714	4.998 4.997	5.001 5.000
	51	7½	1800		O.E.	307	"	3.1496	1.3780	.8268	.8268		.500	1.3780 1.3777	4.124 4.123	4.126 4.125
946	46	5	1200		PULLEY	309	"	3.9370	1.7717	.9843	.9843		.625	1.7717 1.7714	4.998 4.997	5.001 5.000
					O.E.	307	"	3.1496	1.3780	.8268	.8268		.500	1.3780 1.3777	4.124 4.123	4.126 4.125
948	90	10	1800		PULLEY	309	"	3.9370	1.7717	.9843	.9843		.625	1.7717 1.7714	4.998 4.997	5.001 5.000
					O.E.	307	"	3.1496	1.3780	.8268	.8268		.500	1.3780 1.3777	4.124 4.123	4.126 4.125
952	62	5	900		PULLEY	310	"	4.3307	1.9685	1.0630	1.0630		.687	1.9685 1.9682	5.498 5.497	5.501 5.500
	72	7½	1200		O.E.	309	"	3.9370	1.7717	.9843	.9843		.625	1.7717 1.7714	4.998 4.997	5.001 5.000
956	91	10	1200		PULLEY	310	"	4.3307	1.9685	1.0630	1.0630		.687	1.9685 1.9682	5.498 5.497	5.501 5.500
					O.E.	309	"	3.9370	1.7717	.9843	.9843		.625	1.7717 1.7714	4.998 4.997	5.001 5.000
958	90	7½	900		PULLEY	310	"	4.3307	1.9685	1.0630	1.0630		.687	1.9685 1.9682	5.498 5.497	5.501 5.500
					O.E.	309	"	3.9370	1.7717	.9843	.9843		.625	1.7717 1.7714	4.998 4.997	5.001 5.000

60 CYCLE MOTORS

TABLE C-7a

GENERAL ELECTRIC A.C. MOTORS

MOTOR DATA				BEARING DATA											
FRAME	TORQUE	H.P.	R.P.M	M'F'G.	S.A.E. BEARING SIZE	TYPE	A	B	C	D	BALLS Nº	BALLS DIA	SHAFT DIA	CART'G O.D.	SHIELD BORE
M.T. 502	70	15	1200		PULLEY 312	BALL	5.1181	2.3622	1.2205	1.2205		.8125	2.3626 2.3621		5.1194 5.1183
					O.E. 309	"	3.9370	1.7717	.9843	.9843		.625	1.7722 1.7717		3.9383 3.9372
510	62.5	10	900		PULLEY 313	"	5.5118	2.5591	1.2992	1.2992		.875	2.5595 2.5590		5.5131 5.5120
					O.E. 309	"	3.9370	1.7717	.9843	.9843		.625	1.7722 1.7717		3.9383 3.9372
512	92	20	1200		PULLEY 313	"	5.5118	2.5591	1.2992	1.2992		.875	2.5595 2.5590		5.5131 5.5120
	94	15	900		O.E. 309	"	3.9370	1.7717	.9843	.9843		.625	1.7722 1.7717		3.9383 3.9372
522	116	25	1200		PULLEY 315	"	6.2992	2.9528	1.4567	1.4567		1.00	2.9532 2.9527		6.3008 6.2995
	125	20	900		O.E. 312	"	5.1181	2.3622	1.2205	1.2205		.8125	2.3626 2.3621		5.1194 5.1183
526	137	30	1200		PULLEY 315	"	6.2992	2.9528	1.4567	1.4567		1.00	2.9532 2.9527		6.3008 6.2995
	156	25	900		O.E. 312	"	5.1181	2.3622	1.2205	1.2205		.8125	2.3626 2.3621		5.1194 5.1183
532	184	40	1200		PULLEY 318	"	7.4803	3.5433	1.6929	1.6929		1.1875	3.5436 3.5431		7.4820 7.4807
	185	30	900		O.E. 315	"	6.2992	2.9528	1.4567	1.4567		1.00	2.9532 2.9527		6.3008 6.2995
536	211	60	1200		PULLEY 318	"	7.4803	3.5433	1.6929	1.6929		1.1875	3.5436 3.5431		7.4820 7.4807
	247	40	900		O.E. 315	"	6.2992	2.9528	1.4567	1.4567		1.00	2.9532 2.9527		6.3008 6.2995
542	305	50	900		PULLEY 319	"	7.8740	3.7402	1.7717	1.7717		1.25	3.7405 3.7399		7.8761 7.8746
	311	40	720		O.E. 315	"	6.2992	2.9528	1.4567	1.4567		1.00	2.9532 2.9527		6.3008 6.2995
546	366	60	900		PULLEY 319	"	7.8740	3.7402	1.7717	1.7717		1.25	3.7405 3.7399		7.8761 7.8746
	380	50	720		O.E. 315	"	6.2992	2.9528	1.4567	1.4567		1.00	2.9532 2.9527		6.3008 6.2995
552	453	75	900		PULLEY 319	"	7.8740	3.7402	1.7717	1.7717		1.25	3.7405 3.7399		7.8761 7.8746
	456	60	720		O.E. 319	"	7.8740	3.7402	1.7717	1.7717		1.25	3.7405 3.7399		7.8761 7.8746
556	604	100	900		PULLEY	ROLLER	9.4488	4.3307	3.7500	3.7500			4.3327 4.3313		9.4509 9.4494
	548	60	600		O.E. 319	BALL	7.8740	3.7402	1.7717	1.7717		1.25	3.7405 3.7399		7.8761 7.8746
558	746	125	900		PULLEY	ROLLER	9.4488	4.3307	3.7500	3.7500			4.3327 4.3313		9.4509 9.4494
	685	75	600		O.E. 319	BALL	7.8740	3.7402	1.7717	1.7717		1.25	3.7405 3.7399		7.8761 7.8746
562	938	125	720		PULLEY	ROLLER	10.2362	4.7244	4.1250	4.1250			4.7255 4.7247		10.2376 10.2366
	922	100	600		O.E. 322	BALL	9.4488	4.3307	1.9685	1.9685		1.50	4.3310 4.3304		9.4509 9.4494
564	1132	150	720		PULLEY	ROLLER	11.0236	5.1181	4.3750	4.3750			5.1192 5.1184		11.0250 11.0240
	1140	125	600		O.E. 322	BALL	9.4488	4.3307	1.9685	1.9685		1.50	4.3310 4.3304		9.4509 9.4494
566	1500	200	720		PULLEY	ROLLER	11.0236	5.1181	4.3750	4.3750			5.1192 5.1184		11.0250 11.0240
	1810	200	600		O.E. 322	BALL	9.4488	4.3307	1.9685	1.9685		1.50	4.3310 4.3304		9.4509 9.4494

60 CYCLE MOTORS

SEE TABLE A1 FOR A-B-C SKETCH OF ROLLER BEARING

TABLE C-7b

General Electric D.C. Motors

Motor Data					Bearing Data												
Frame	Torque	H.P.	R.P.M.	M'f'g.	S.A.E. Bearing Size		Type	A	B	C	D	Balls Nº	Balls Dia.	Shaft Dia	Cart'g O.D.	Shield Bore
BD 27	3.0	1	1750		Pulley	305	Ball	2.4409	.9843	.6693	.6693		.375	.9843 .9840	3.2490 3.2480	3.2510 3.2500
					Comm	304	"	2.0472	.7874	.5906	.5906		.312	.7874 .7871	2.8740 2.8730	2.8760 2.8750
33	3.4	¾	1150		Pulley	306	"	2.8346	1.1811	.7480	.7480		.437	1.1811 1.1808	3.6240 3.6230	3.6260 3.6250
	4.6	1	1150													
	4.5	1½	1750		Comm	304	"	2.0472	.7874	.5906	.5906		.312	.7874 .7871	2.8740 2.8730	2.8760 2.8750
35	6.0	2	1750		Pulley	306	"	2.8346	1.1811	.7480	.7480		.437	1.1811 1.1808	3.6240 3.6230	3.6260 3.6250
					Comm	304	"	2.0472	.7874	.5906	.5906		.312	.7874 .7871	2.8740 2.8730	2.8760 2.8750
43	6.8	1½	1150		Pulley	307	"	3.1496	1.3780	.8268	.8268		.500	1.3780 1.3777	4.1240 4.1230	4.1260 4.1250
					Comm	305	"	2.4409	.9843	.6693	.6693		.375	.9843 .9840	3.2490 3.2480	3.2510 3.2500
45	9.1	2	1150		Pulley	307	"	3.1496	1.3780	.8268	.8268		.500	1.3780 1.3777	4.1240 4.1230	4.1260 4.1250
	9.0	3	1750		Comm	305	"	2.4409	.9843	.6693	.6693		.375	.9843 .9840	3.2490 3.2480	3.2510 3.2500
C.D 55	12.3	2	850		Pulley	307	"	3.1496	1.3780	.8268	.8268		.500	1.3780 1.3777	4.1240 4.1230	4.1260 4.1250
	13.6	3	1150													
	15.0	5	1750		Comm	305	"	2.4409	.9843	.6693	.6693		.375	.9843 .9840	3.2490 3.2480	4.1260 4.1250
65	18.5	3	850		Pulley	308	"	3.5433	1.5748	.9055	.9055		.562	1.5748 1.5745	4.6230 4.6220	4.6260 4.6250
	22.8	5	1150													
	22.5	7½	1750		Comm	306	"	2.8346	1.1811	.7480	.7480		.437	1.1811 1.1808	3.6240 3.6230	3.6260 3.6250
73	30.9	5	850		Pulley	310	"	4.3307	1.9685	1.0630	1.0630		.687	1.9685 1.9682	5.4980 5.4970	5.5010 5.5000
	34.2	7½	1150													
	30.0	10	1750		Comm	308	"	3.5433	1.5748	.9055	.9055		.562	1.5748 1.5745	4.6230 4.6220	4.6260 4.6250
75	46.3	7½	850		Pulley	310	"	4.3307	1.9685	1.0630	1.0630		.687	1.9685 1.9682	5.4980 5.4970	5.5010 5.5000
	45.6	10	1150													
	45.0	15	1750		Comm	308	"	3.5433	1.5748	.9055	.9055		.562	1.5748 1.5745	4.6230 4.6220	4.6260 4.6250
83	61.8	10	850		Pulley	313	"	5.5118	2.5591	1.2992	1.2992		.875	2.5591 2.5588	6.7480 6.7470	6.7510 6.7500
	68.5	15	1150													
	60.0	20	1750		Comm	310	"	4.3307	1.9685	1.0630	1.0630		.687	1.9685 1.9682	5.4980 5.4970	5.5010 5.5000
85	92.7	15	850		Pulley	313	"	5.5118	2.5591	1.2992	1.2992		.875	2.5591 2.5588	6.7480 6.7470	6.7510 6.7500
	91.3	20	1150													
	75	25	1750		Comm	310	"	4.3307	1.9685	1.0630	1.0630		.687	1.9685 1.9682	5.4980 5.4970	5.5010 5.5000
	40.0	30	1750													
93	114.1	25	1150		Pulley	314	"	5.9055	2.7559	1.3780	1.3780		.937	2.7559 2.7556	7.1855 7.1845	7.1885 7.1875
	120	40	1750		Comm	311	"	4.7244	2.1654	1.1417	1.1417		.750	2.1654 2.1651	5.9980 5.9970	6.0010 6.0000
95	123.8	20	850		Pulley	314	"	5.9055	2.7559	1.3780	1.3780		.937	2.7559 2.7556	7.1855 7.1845	7.1885 7.1875
	137	30	1150		Comm	311	"	4.7244	2.1654	1.1417	1.1417		.750	2.1654 2.1651	5.9980 5.9970	6.0010 6.0000
103	154.5	25	850		Pulley	317	"	7.0866	3.3465	1.6142	1.6142		1.125	3.3468 3.3463	None	7.0882 7.0869
	182	40	1150		Comm	312	"	5.1181	2.3622	1.2205	1.2205		.812	2.3626 2.3621	"	5.1194 5.1183
105	182.9	20	575		Pulley	317	"	7.0866	3.3465	1.6142	1.6142		1.125	3.3468 3.3463	"	7.0882 7.0869
	185	30	850													
	228	50	1150		Comm	312	"	5.1181	2.3622	1.2205	1.2205		.812	2.3626 2.3621	"	5.1194 5.1183
113	228.1	25	575		Pulley	319	"	7.8740	3.7402	1.7717	1.7717		1.250	3.7405 3.7399	"	7.8761 7.8746
	247	40	850													
	274	60	1150		Comm	314	"	5.9055	2.7559	1.3780	1.3780		.937	2.7563 2.7558	"	5.9071 5.9058
115	274	30	575		Pulley	319	"	7.8740	3.7402	1.7717	1.7717		1.250	3.7405 3.7399	"	7.8761 7.8746
	309	50	850													
	342	75	1150		Comm	314	"	5.9055	2.7559	1.3780	1.3780		.937	2.7563 2.7558	"	5.9071 5.9058
123	365	40	575		Pulley	320	"	8.4646	3.9370	1.8504	1.8504		1.312	3.9373 3.9367	"	8.4666 8.4651
	370	60	850													
	457	100	1150		Comm	315	"	6.2992	2.9528	1.4567	1.4567		1.00	2.9532 2.9527	"	6.3008 6.2995
125	457	50	575		Pulley	320	"	8.4646	3.9370	1.8504	1.8504		1.312	3.9373 3.9367	"	8.4666 8.4651
	464	75	850													
	618	100	850		Comm	315	"	6.2992	2.9528	1.4567	1.4567		1.00	2.9532 2.9527	"	6.3008 6.2995

TABLE C-8

ALLIS-CHALMERS D.C. MOTORS

MOTOR DATA				BEARING DATA											
FRAME	TORQUE	H.P.	R.P.M.	M'F'G.	S.A.E. BEARING SIZE	TYPE	A	B	C	D	ROLLER Nº	ROLLER DIA	SHAFT DIA.	CART'G O.D.	FRAME BORE
E	2.5	½	1150	TIMKEN	PULLEY 8304	ROLLER	2.0464 2.0472	.7870 .7874	.8750	.8750	24	.312	.7882 .7877		2.0481 2.0473
30	3.0	1	1750		COMM 8304	"	2.0464 2.0472	.7870 .7874	.8750	.8750	24	.312	.7882 .7877		2.0481 2.0473
50	4.75	1	1150	"	PULLEY 8306	"	2.8338 2.8346	1.1806 1.1811	1.1875	1.1875	28	.375	1.1819 1.1814		2.8355 2.8347
	6.0	2	1750		COMM 8305	"	2.4401 2.4409	.9838 .9842	1.000	1.000	32	.312	.9850 .9845		2.4418 2.4410
51	6.25	1	850	"	PULLEY 8306	"	2.8338 2.8346	1.1806 1.1811	1.1875	1.1875	28	.375	1.1819 1.1814		2.8355 2.8347
	9.25	2	1150		COMM 8305	"	2.4401 2.4409	.9838 .9842	1.000	1.000	32	.312	.9850 .9845		2.4418 2.4410
	9.00	3	1750												
65	12.5	2	850	"	PULLEY 8307	"	3.1488 3.1496	1.3774 1.3779	1.3750	1.3750	32	.375	1.3787 1.3782		3.1506 3.1498
	13.75	3	1150		COMM 8306	"	2.8338 2.8346	1.1806 1.1811	1.1875	1.1875	28	.375	1.1819 1.1814		2.8355 2.8347
	15.0	5	1750												
70	18.5	3	850	"	PULLEY 8308	"	3.5425 3.5433	1.5743 1.5748	1.4375	1.4375	28	.484	1.5756 1.5751		3.5443 3.5435
	23.0	5	1150		COMM 8306	"	2.8338 2.8346	1.1806 1.1811	1.1875	1.1875	28	.375	1.1819 1.1814		2.8355 2.8347
	22.5	7½	1750												
75	31.0	5	850	"	PULLEY 8308	"	3.5425 3.5433	1.5743 1.5748	1.4375	1.4375	28	.484	1.5756 1.5751		3.5443 3.5435
	34.25	7½	1150		COMM 8306	"	2.8338 2.8346	1.1806 1.1811	1.1875	1.1875	28	.375	1.1819 1.1814		2.8355 2.8347
	30.0	10	1750												
80	46.5	7½	850	"	PULLEY 8309	"	3.9362 3.9370	1.7712 1.7717	1.5625	1.5625	32	.484	1.7725 1.7720		3.9382 3.9372
	45.75	10	1150		COMM 8308	"	3.5425 3.5433	1.5743 1.5748	1.4375	1.4375	28	.484	1.5756 1.5751		3.5443 3.5435
	45.0	15	1750												
90	62.0	10	850	"	PULLEY 8310	"	4.3299 4.3307	1.9680 1.9685	1.7500	1.7500	28	.594	1.9693 1.9688		4.3319 4.3309
	68.5	15	1150		COMM 8309	"	3.9362 3.9370	1.7712 1.7717	1.5625	1.5625	32	.484	1.7725 1.7720		3.9382 3.9372
	60.0	20	1750												
	75.0	25	1750												
100	93.0	15	850	"	PULLEY 8312	"	5.1173 5.1181	2.3616 2.3622	2.1250	2.1250	28	.703	2.3631 2.3625		5.1193 5.1183
	91.5	20	1150		COMM 8310	"	4.3299 4.3307	1.9680 1.9685	1.7500	1.7500	28	.594	1.9693 1.9688		4.3319 4.3309
	114.0	25	1150												
	90.0	30	1750												
120	123.5	20	850	"	PULLEY 8314	"	5.9043 5.9055	2.7553 2.7559	2.500	2.500	28	.812	2.7568 2.7562		5.9067 5.9057
	154.5	25	850		COMM 8312	"	5.1173 5.1181	2.3616 2.3622	2.1250	2.1250	28	.703	2.3631 2.3625		5.1193 5.1183
	137.0	30	1150												
	183.0	40	1150												
121	123.5	20	850	"	PULLEY 8314	"	5.9043 5.9055	2.7553 2.7559	2.500	2.500	28	.812	2.7568 2.7562		5.9067 5.9057
	154.5	25	850		COMM 8312	"	5.1173 5.1181	2.3616 2.3622	2.1250	2.1250	28	.703	2.3631 2.3625		5.1193 5.1183
	137.0	30	1150												
	120.0	40	1750												
122	183.0	20	575	"	PULLEY 8314	"	5.9043 5.9055	2.7553 2.7559	2.500	2.500	28	.812	2.7568 2.7562		5.9067 5.9057
	185.5	30	850		COMM 8312	"	5.1173 5.1181	2.3616 2.3622	2.1250	2.1250	28	.703	2.3631 2.3625		5.1193 5.1183
123	183.0	20	575	"	PULLEY 8314	"	5.9043 5.9055	2.7553 2.7559	2.500	2.500	28	.812	2.7568 2.7562		5.9067 5.9057
	185.5	30	850		COMM 8312	"	5.1173 5.1181	2.3616 2.3622	2.1250	2.1250	28	.703	2.3631 2.3625		5.1193 5.1183
	183.0	40	1150												
	150.0	50	1750												
130	228.5	25	575	"	PULLEY 8316	"	6.6917 6.6929	3.1490 3.1496	2.6875	2.6875	28	.922	3.1505 3.1499		6.6941 6.6931
					COMM 8313	"	5.5110 5.5118	2.5585 2.5591	2.3125	2.3125	32	.703	2.5600 2.5594		5.5130 5.5120
131	228.5	25	575	"	PULLEY 8316	"	6.6917 6.6929	3.1490 3.1496	2.6875	2.6875	28	.922	3.1505 3.1499		6.6941 6.6931
	247.0	40	850												
	228.0	50	1150												
	180.0	60	1750		COMM 8313	"	5.5110 5.5118	2.5585 2.5591	2.3125	2.3125	32	.703	2.5600 2.5594		5.5130 5.5120
	225.0	75	1750												
145	274.0	30	575	"	PULLEY 8318	"	7.4791 7.4803	3.5426 3.5433	2.8750	2.8750	28	1.031	3.5443 3.5436		7.4816 7.4806
	366.0	40	575		COMM 8315	"	6.2980 6.2992	2.9522 2.9528	2.6875	2.6875	32	.812	2.9537 2.9531		6.3004 6.2994
146	366.0	40	575	"	PULLEY 8318	"	7.4791 7.4803	3.5426 3.5433	2.8750	2.8750	28	1.031	3.5443 3.5436		7.4816 7.4806
	309.0	50	850												
	274.0	60	1150												
	371.0	60	850		COMM 8315	"	6.2980 6.2992	2.9522 2.9528	2.6875	2.6875	32	.812	2.9537 2.9531		6.3004 6.2994
	342.0	75	1150												
	463.0	75	850												
147	457.0	50	575	"	PULLEY 8318	"	7.4791 7.4803	3.5426 3.5433	2.875	2.875	28	1.031	3.5443 3.5436		7.4816 7.4806
	548.0	60	575												
	457.0	100	1150		COMM 8315	"	6.2980 6.2992	2.9522 2.9528	2.6875	2.6875	32	.812	2.9537 2.9531		6.3004 6.2994

CONSTANT SPEED MOTORS

SEE TABLE A1 FOR A-B-C SKETCH OF ROLLER BEARING

TABLE C-9

ALLIS CHALMERS A.C. MOTORS

MOTOR DATA				BEARING DATA												
FRAME	TORQUE	H.P.	R.P.M.	M'F'G.	S.A.E BEARING SIZE		TYPE	A	B	C	D	ROLLER Nº	ROLLER DIA.	SHAFT DIA.	CART'G O.D.	FRAME BORE
307C	3	1	1720	TIMKEN	PULLEY	1755-1729	ROLLER	2.2410 2.2400	.8760 .8750	.6250	.7810			.8769 .8760		2.2410 2.2400
					O.E.	1755-1729	"	2.2410 2.2400	.8760 .8750	.6250	.7810			.8769 .8760		2.2410 2.2400
308C	6	1	1140	"	PULLEY	26118-26283	"	2.8355 2.8345	1.1815 1.1805	.6250	.7450			1.1824 1.1815		2.8355 2.8345
		2	1720		O.E.	26118-26283	"	2.8355 2.8345	1.1815 1.1805	.6250	.7450			1.1824 1.1815		2.8355 2.8345
308D	9	1	850	"	PULLEY	26118-26283	"	2.8355 2.8345	1.1815 1.1805	.6250	.7450			1.1824 1.1815		2.8355 2.8345
		1½	1140													
		2	1140		O.E.	26118-26283	"	2.8355 2.8345	1.1815 1.1805	.6250	.7450			1.1824 1.1815		2.8355 2.8345
		3	1720													
310C	15	2	850	"	PULLEY	418-414	"	3.4853 3.4843	1.5010 1.5000	.8750	1.1450			1.5019 1.5010		3.4853 3.4843
		3	1140													
		5	1720		O.E.	418-414	"	3.4853 3.4843	1.5010 1.5000	.8750	1.1450			1.5019 1.5010		3.4853 3.4843
310D	22.5	3	850	"	PULLEY	418-414	"	3.4853 3.4843	1.5010 1.5000	.8750	1.1450			1.5019 1.5010		3.4853 3.4843
		5	1140													
		7½	1720		O.E.	418-414	"	3.4853 3.4843	1.5010 1.5000	.8750	1.1450			1.5019 1.5010		3.4853 3.4843
313C	30	3	675	"	PULLEY	438-432	"	3.7510 3.7500	1.7510 1.7500	.8750	1.1772			1.7519 1.7510		3.7510 3.7500
		5	850													
		7½	1140		O.E.	438-432	"	3.7510 3.7500	1.7510 1.7500	.8750	1.1772			1.7519 1.7510		3.7510 3.7500
		10	1730													
313D	45	5	675	"	PULLEY	438-432	"	3.7510 3.7500	1.7510 1.7500	.8750	1.1772			1.7519 1.7510		3.7510 3.7500
		7½	850													
		10	1150		O.E.	438-432	"	3.7510 3.7500	1.7510 1.7500	.8750	1.1772			1.7519 1.7510		3.7510 3.7500
		15	1730													
416C	75	5	570	"	PULLEY	537-532	"	4.3760 4.3750	2.0010 2.0000	1.1875	1.4550			2.0019 2.0010		4.3760 4.3750
		7½	690													
		10	860													
		15	1150		O.E.	537-532	"	4.3760 4.3750	2.0010 2.0000	1.1875	1.4550			2.0019 2.0010		4.3760 4.3750
		20	1740													
		25	1740													
416D	90	7½	570	"	PULLEY	537-532	"	4.3760 4.3750	2.0010 2.0000	1.1875	1.4550			2.0019 2.0010		4.3760 4.3750
		10	690													
		15	860													
		20	1150		O.E.	537-532	"	4.3760 4.3750	2.0010 2.0000	1.1875	1.4550			2.0019 2.0010		4.3760 4.3750
		30	1740													
417C	112.5	10	575	"	PULLEY	5584-5521	"	5.1191 5.1181	2.5010 2.5000	1.4375	1.7230			2.5019 2.5010		5.1190 5.1181
		25	1150		O.E.	5584-5521	"	5.1191 5.1181	2.5010 2.5000	1.4375	1.7230			2.5019 2.5010		5.1190 5.1181
417D	135	15	680	"	PULLEY	5584-5521	"	5.1191 5.1181	2.0010 2.5000	1.4375	1.7230			2.5019 2.5010		5.1190 5.1181
		20	860													
		30	1155		O.E.	5584-5521	"	5.1191 5.1181	2.0010 2.5000	1.4375	1.7230			2.5019 2.5010		5.1190 5.1181
420C	180	15	575	"	PULLEY	6455-6420	"	5.8760 5.8750	2.2510 2.2500	1.7500	2.1350			2.7519 2.7510		5.8760 5.8750
		20	685													
		25	865													
		30	865		O.E.	6455-6420	"	5.8760 5.8750	2.2510 2.2500	1.7500	2.1350			2.7519 2.7510		5.8760 5.8750
		40	1155													
420D	240	20	575	"	PULLEY	6455-6420	"	5.8760 5.8750	2.2510 2.2500	1.7500	2.1350			2.7519 2.7510		5.8760 5.8750
		25	685													
		30	685		O.E.	6455-6420	"	5.8760 5.8750	2.2510 2.2500	1.7500	2.1350			2.7519 2.7510		5.8760 5.8750
		40	860													
423C	300	25	575	"	PULLEY	6461-6420	"	5.8760 5.8750	3.0010 3.0000	1.7500	2.1350			3.0019 3.0010		5.8760 5.8750
		30	575													
		40	690		O.E.	6461-6420	"	5.8760 5.8750	3.0010 3.0000	1.7500	2.1350			3.0019 3.0010		5.8760 5.8750
		50	865													
423D	360	40	575	"	PULLEY	6461-6420	"	5.8760 5.8750	3.0010 3.0000	1.7500	2.1350			3.0019 3.0010		5.8760 5.8750
		50	690													
		60	865		O.E.	6461-6420	"	5.8760 5.8750	3.0010 3.0000	1.7500	2.1350			3.0019 3.0010		5.8760 5.8750
426C	450	40	490	"	PULLEY	6580-6520	"	6.6880 6.6870	3.5010 3.5000	1.7500	2.1693			3.5019 3.5010		6.6880 6.6870
		50	575													
		60	960		O.E.	6580-6520	"	6.6880 6.6870	3.5010 3.5000	1.7500	2.1693			3.5019 3.5010		6.6880 6.6870
		75	865													
426D	600	50	490	"	PULLEY	6580-6520	"	6.6880 6.6870	3.5010 3.5000	1.7500	2.1693			3.5019 3.5010		6.6880 6.6870
		60	575													
		75	690		O.E.	6580-6520	"	6.6880 6.6870	3.5010 3.5000	1.7500	2.1693			3.5019 3.5010		6.6880 6.6870
		100	865													
426EH	750	50	430	"	PULLEY	861-852	"	7.5010 7.5000	4.0010 4.0000	1.8750	2.2650			4.0019 4.0010		7.5010 7.5000
		60	495													
		75	580													
		100	695		O.E.	861-852	"	7.5010 7.5000	4.0010 4.0000	1.8750	2.2650			4.0019 4.0010		7.5010 7.5000
			870													

TABLE C-9a

CROCKER WHEELER A.C. MOTORS

MOTOR DATA				BEARING DATA												
FRAME	TORQUE	H.P.	R.P.M	M'F'G.	S.A.E. BEARING SIZE		TYPE	A	B	C	D	BALLS Nº	BALLS DIA	SHAFT DIA.	CART'G O.D.	FRAME BORE
10P	1.75	½	1500		PULLEY	305	BALL	2.44095	.98425	.66929	.66929			.9845 .9848	NONE	2.4410 2.4420
					O.E.	305	"	2.44095	.98425	.66929	.66929			.9845 .9848	"	2.4410 2.4420
15P	3.5	½	750		PULLEY	306	"	2.83465	1.18110	.74803	.74803			1.1813 1.1816	"	2.8350 2.8360
	3.5	1	1500		O.E.	306	"	2.83465	1.18110	.74803	.74803			1.1813 1.1816	"	2.8350 2.8360
20P	5.25	¾	750		PULLEY	306	"	2.83465	1.18110	.74803	.74803			1.1813 1.1816	"	2.8350 2.8360
	5.25	1½	1500		O.E.	306	"	2.83465	1.18110	.74803	.74803			1.1813 1.1816	"	2.8350 2.8360
30P	7.0	1	750		PULLEY	306	"	2.83465	1.18110	.74803	.74803			1.1813 1.1816	"	2.8350 2.8360
					O.E	306	"	2.83465	1.18110	.74803	.74803			1.1813 1.1816	"	2.8350 2.8360
40P	7.0	2	1500		PULLEY	307	"	3.14962	1.37795	.82677	.82677			1.3782 1.3787	"	3.1500 3.1510
	14	2	750		O.E	307	"	3.14962	1.37795	.82677	.82677			1.3782 1.3787	"	3.1500 3.1510
50P	10.5	3	1500		PULLEY	308	"	3.54332	1.57481	.90551	.90551			1.5750 1.5755	"	3.5435 3.5445
	21.0	3	750		O.E.	308	"	3.54332	1.57481	.90551	.90551			1.5750 1.5755	"	3.5435 3.5445
60P	17.5	5	1500		PULLEY	310	"	4.33072	1.96851	1.06299	1.06299			1.9687 1.9692	"	4.3315 4.3325
	35.0	5	750		O.E.	310	"	4.33072	1.96851	1.06299	1.06299			1.9687 1.9692	"	4.3315 4.3325
20Y	26.25	7½	1500		PULLEY	311	"	4.72443	2.16536	1.14173	1.14173			2.1656 2.1661	"	4.7250 4.7260
					O.E.	311	"	4.72443	2.16536	1.14173	1.14173			2.1656 2.1661	"	4.7250 4.7260
25Y	52.5	7½	750		PULLEY	312	"	5.11813	2.36221	1.22047	1.22047			2.3624 2.3629	"	5.1190 5.1200
	35.0	10	1500		O.E.	312	"	5.11813	2.36221	1.22047	1.22047			2.3624 2.3629	"	5.1190 5.1200
30Y	70.0	10	750		PULLEY	314	"	5.90455	2.75591	1.37795	1.37795			2.7561 2.7566	"	5.9060 5.9070
	32.5	15	1500		O.E.	314	"	5.90455	2.75591	1.37795	1.37795			2.7561 2.7566	"	5.9060 5.9070
35Y	105	15	750		PULLEY	316	"	6.69294	3.14962	1.53544	1.53544			3.1498 3.1503	"	6.6940 6.6950
	70.0	20	1500		O.E.	316	"	6.69294	3.14962	1.53544	1.53544			3.1498 3.1503	"	6.6940 6.6950
40Y	140	20	750		PULLEY	317	"	7.08664	3.34647	1.61418	1.61418			3.3467 3.3472	"	7.0870 7.0880
	87.5	25	1500		O.E.	317	"	7.08664	3.34647	1.61418	1.61418			3.3467 3.3472	"	7.0870 7.0880
*41Y	105	30	1500		PULLEY	314	"	5.90455	2.75591	1.37795	1.37795			2.7561 2.7566	"	5.9060 5.9070
					O.E.	314	"	5.90455	2.75591	1.37795	1.37795			2.7561 2.7566	"	5.9060 5.9070
55Y	210.0	30	750		PULLEY	319	"	7.87405	3.74017	1.77166	1.77166			3.7404 3.7409	"	7.8750 7.8760
					O.E.	319	"	7.87405	3.74017	1.77166	1.77166			3.7404 3.7409	"	7.8750 7.8760
*51Y	140	40	1500		PULLEY	314	"	5.90455	2.75591	1.37795	1.37795			2.7561 2.7566	"	5.9060 5.9070
					O.E.	314	"	5.90455	2.75591	1.37795	1.37795			2.7561 2.7566	"	5.9060 5.9070
65Y	280	40	750		PULLEY	319	ROLLER	7.87405	3.74017	1.77166	1.77166			3.7404 3.7409	"	7.8750 7.8760
					O.E.	319	BALL	7.87405	3.74017	1.77166	1.77166			3.7404 3.7409	"	7.8750 7.8760

25 CYCLE MOTORS

SEE TABLE A1 FOR A-B-C SKETCH OF ROLLER BEARING

* FOR COUPLED DUTY. IF USED FOR BELTED DUTY ROLLER BEARING WILL BE USED ON PULLEY END.

TABLE C-10

CROCKER WHEELER A.C. MOTORS

MOTOR DATA				BEARING DATA													
FRAME	TORQUE	H.P.	R.P.M.	M'F'G.	S.A.E. BEARING SIZE		TYPE	A	B	C	D	BALLS Nº	BALLS DIA.	SHAFT DIA.	CART'G O.D.	FRAME BORE
5P			900		PULLEY	304	BALL	2.04725	.78740	.59055	.59055			.7876 .7879	NONE	2.0473 2.0483
	1.14	¼	1200		O.E.	304	"	2.04725	.78740	.59055	.59055			.7876 .7879	"	2.0473 2.0483
	1.50	½	1800													
10P	1.54	¼	900		PULLEY	305	"	2.44095	.98425	.66929	.66929			.9845 .9848	"	2.4410 2.4420
	2.28	½	1200		O.E.	305	"	2.44095	.98425	.66929	.66929			.9845 .9848	"	2.4410 2.4420
	3.00	1	1800													
15P	3.08	½	900		PULLEY	306	"	2.83465	1.18110	.74803	.74803			1.1813 1.1816	"	2.8350 2.8360
	4.56	1	1200		O.E.	306	"	2.83465	1.18110	.74803	.74803			1.1813 1.1816	"	2.8350 2.8360
	4.50	1½	1800													
20P	4.62	¾	900		PULLEY	306	"	2.83465	1.18110	.74803	.74803			1.1813 1.1816	"	2.8350 2.8360
	6.84	1½	1200		O.E.	306	"	2.83465	1.18110	.74803	.74803			1.1813 1.1816	"	2.8350 2.8360
	6.00	2	1800													
30P	9.24	1½	900		PULLEY	306	"	2.83465	1.18110	.74803	.74803			1.1813 1.1816	"	2.8350 2.8360
	9.12	2	1200		O.E.	306	"	2.83465	1.18110	.74803	.74803			1.1813 1.1816	"	2.8350 2.8360
	9.00	3	1800													
40P	12.32	2	900		PULLEY	307	"	3.14962	1.37795	.82677	.82677			1.3782 1.3787	"	3.1500 3.1510
	13.68	3	1200		O.E.	307	"	3.14962	1.37795	.82677	.82677			1.3782 1.3787	"	3.1500 3.1510
	15.00	5	1800													
50P	18.48	3	900		PULLEY	308	"	3.54332	1.57481	.90551	.90551			1.5750 1.5755	"	3.5435 3.5445
	22.80	5	1200		O.E.	308	"	3.54332	1.57481	.90551	.90551			1.5750 1.5755	"	3.5435 3.5445
	22.50	7½	1800													
60P	30.80	5	900		PULLEY	310	"	4.33072	1.96851	1.06299	1.06299			1.9687 1.9692	"	4.3315 4.3325
	34.20	7½	1200		O.E	310	"	4.33072	1.96851	1.06299	1.06299			1.9687 1.9692	"	4.3315 4.3325
	30.00	10	1800													
20Y	46.20	7½	900		PULLEY	311	"	4.72443	2.16536	1.14173	1.14173			2.1656 2.1661	"	4.7250 4.7260
	45.60	10	1200		O.E.	311	"	4.72443	2.16536	1.14173	1.14173			2.1656 2.1661	"	4.7250 4.7260
	45.00	15	1800													
25Y	61.60	10	900		PULLEY	312	"	5.11813	2.36221	1.22047	1.22047			2.3624 2.3629	"	5.1190 5.1200
	68.40	15	1200		O.E	312	"	5.11813	2.36221	1.22047	1.22047			2.3624 2.3629	"	5.1190 5.1200
	60.00	20	1800													
30Y	92.40	15	900		PULLEY	314	"	5.90554	2.75591	1.37795	1.37795			2.7561 2.7566	"	5.9060 5.9070
	91.20	20	1200		O.E	314	"	5.90554	2.75591	1.37795	1.37795			2.7561 2.7566	"	5.9060 5.9070
	90.00	30	1800													
35Y	123.20	20	900		PULLEY	316	"	6.69294	3.14962	1.53544	1.53544			3.1498 3.1503	"	6.6940 6.6950
	114.00	25	1200		O.E.	316	"	6.69294	3.14962	1.53544	1.53544			3.1498 3.1503	"	6.6940 6.6950
	120.00	40	1800													
40Y	154.00	25	900		PULLEY	317	"	7.08664	3.34647	1.61418	1.61418			3.3467 3.3472	"	7.0870 7.0880
	136.80	30	1200		O.E.	317	"	7.08664	3.34647	1.61418	1.61418			3.3467 3.3472	"	7.0870 7.0880
	150.00	50	1800													
50Y	184.80	30	900		PULLEY	317	"	7.08664	3.34647	1.61418	1.61418			3.3467 3.3472	"	7.0870 7.0880
	182.40	40	1200		O.E.	317	"	7.08664	3.34647	1.61418	1.61418			3.3467 3.3472	"	7.0870 7.0880
	180.00	60	1800													
55Y	246.40	40	900		PULLEY	319	"	7.87405	3.74017	1.77166	1.77166			3.7404 3.7409	"	7.8750 7.8760
	228.00	50	1200		O.E.	319	"	7.87405	3.74017	1.77166	1.77166			3.7404 3.7409	"	7.8750 7.8760
	225.00	75	1800													
65Y	308.00	50	900		PULLEY	319	ROLLER	7.87405	3.74017	1.77166	1.77166			3.7404 3.7409	"	7.8750 7.8760
	369.0	60	900													
	342.0	75	1200		O.E	319	"	7.87405	3.74017	1.77166	1.77166			3.7404 3.7409	"	7.8750 7.8760
	300.0	100	1800													

60 CYCLE MOTORS

SEE TABLE A1 FOR A-B-C SKETCH OF ROLLER BEARING

TABLE C-11

CROCKER WHEELER D.C. MOTORS

MOTOR DATA				BEARING DATA											
FRAME	TORQUE	H.P.	R.P.M.	M'F'G.	S.A.E. BEARING SIZE		TYPE	A	B	C	D	BALLS Nº	BALLS DIA.	SHAFT DIA.	CART'G O.D.	FRAME BORE
AH	30.8	5	850		PULLEY	310	BALL	4.33072	1.96851	1.06299	1.06299			1.9687 1.9692	NONE	4.3315 4.3325
	34.2	7½	1150		COMM.	307	"	3.14962	1.37795	.82677	.82677			1.3782 1.3787	"	3.1500 3.1510
	30.0	10	1750													
BH	46.2	7½	850		PULLEY	311	"	4.72443	2.16536	1.14173	1.14173			2.1656 2.1661	"	4.7250 4.7260
	45.6	10	1150		COMM.	308	"	3.54332	1.57481	.90551	.90551			1.5750 1.5755	"	3.5435 3.5445
	45.0	15	1750													
CH	61.6	10	850		PULLEY	312	"	5.11813	2.36221	1.22047	1.22047			2.3624 2.3629	"	5.1190 5.1200
	68.4	15	1150		COMM	310	"	4.33072	1.96851	1.06299	1.06299			1.9687 1.9692	"	4.3315 4.3325
	60.0	20	1750													
DH	92.4	15	850		PULLEY	315	"	6.29924	2.95277	1.45669	1.45669			2.9530 2.9535	"	6.3000 6.3010
	91.2	20	1150		COMM	311	"	4.72443	2.16536	1.14173	1.14173			2.1656 2.1661	"	4.7250 4.7260
	90.0	30	1750													
EH	123.2	20	850		PULLEY	317	"	7.08664	3.34647	1.61418	1.61418			3.3467 3.3472	"	7.0870 7.0880
	114.0	25	1150		COMM	312	"	5.11813	2.36221	1.22047	1.22047			2.3624 2.3629	"	5.1190 5.1200
	120.0	40	1750													
FH	154.0	25	850		PULLEY	318	"	7.48035	3.54332	1.69292	1.69292			3.5435 3.5440	"	7.4810 7.4820
	184.8	30	850													
	159.6	35	1150													
	182.4	40	1150		COMM	312	"	5.11813	2.36221	1.22047	1.22047			2.3624 2.3629	"	5.1190 5.1200
	150.0	50	1750													
GH	215.6	35	850		PULLEY	318	ROLLER	7.48035	3.54332	1.69292	1.69292			35435 3.5440	"	7.4810 7.4820
	246.4	40	850													
	228.0	50	1150		COMM	312	BALL	5.11813	2.36221	1.22047	1.22047			2.3624 2.3629	"	5.1190 5.1200
	225.0	75	1750													
HH	246.4	40	850		PULLEY	320	ROLLER	8.46460	3.93702	1.85040	1.85040			3.9372 3.9377	"	8.4650 8.4660
	308.0	50	850													
	296.4	65	1150													
	342.0	75	1150		COMM	315	BALL	6.29924	2.95277	1.45669	1.45669			2.9530 2.9535	"	6.3000 6.3010
	255.0	85	1750													
	300.0	100	1750													
HHL	369.6	60	850		PULLEY	320	ROLLER	8.46460	3.93702	1.85040	1.85040			3.9372 3.9377	"	8.4650 8.4660
	387.6	85	1150		COMM	315	BALL	6.29924	2.95277	1.45669	1.45669			2.9530 2.9535	"	6.3000 6.3010
	375.0	125	1750													
DF	3.08	½	850		PULLEY	305	"	2.44095	.98425	.66929	.66929			.9845 .9848	"	2.4410 2.4420
	3.42	¾	1150		COMM	304	"	2.04725	.78740	.59055	.59055			.7876 .7879	"	2.0473 2.0483
	3.00	1	1750													
EF	4.62	¾	850		PULLEY	305	"	2.44095	.98425	.66929	.66929			.9845 .9848	"	2.4410 2.4420
	4.56	1	1150		COMM	304	"	2.04725	.78740	.59055	.59055			.7876 .7879	"	2.0473 2.0483
	4.50	1½	1750													
FF	6.16	1	850		PULLEY	307	"	3.14962	1.37795	.82677	.82677			1.3782 1.3787	"	3.1500 3.1510
	6.84	1½	1150		COMM	305	"	2.44095	.98425	.66929	.66929			.9845 .9848	"	2.4410 2.4420
	6.00	2	1750													
GF	9.24	1½	850		PULLEY	307	"	3.14962	1.37795	.82677	.82677			1.3782 1.3787	"	3.1500 3.1510
	9.12	2	1150		COMM	305	"	2.44095	.98425	.66929	.66929			.9845 .9848	"	2.4410 2.4420
	9.00	3	1750													
HF	12.32	2	850		PULLEY	308	"	3.54332	1.57481	.90551	.90551			1.5750 1.5755	"	3.5435 3.5445
	13.68	3	1150		COMM	306	"	2.83465	1.18110	.74803	.74803			1.1813 1.1816	"	2.8350 2.8360
	15.00	5	1750													
IF	18.48	3	850		PULLEY	308	"	3.54332	1.57481	.90551	.90551			1.5750 1.5755	"	3.5435 3.5445
	22.80	5	1150		COMM	306	"	2.83465	1.18110	.74803	.74803			1.1813 1.1816	"	2.8350 2.8360
	22.5	7½	1750													

SEE TABLE A1 FOR A-B-C SKETCH OF ROLLER BEARING

TABLE C-12

CROCKER WHEELER D.C. MOTORS

MOTOR DATA				BEARING DATA											
FRAME	TORQUE	H.P.	R.P.M.	M'F'G.	S.A.E BEARING SIZE		TYPE	A	B	C	D	BALLS Nº	BALLS DIA.	SHAFT DIA.	CARTG O.D.	FRAME BORE
50H	375	25	350		PULLEY	318	ROLLER	7.48035	3.54332	1.69292	1.69292			3.5435 3.5440	NONE	7.4810 7.4820
	339	30	465													
	350	35	525													
	375	50	700		COMM	316	BALL	6.69294	3.14962	1.53544	1.53544			3.1498 3.1503	"	6.6940 6.6950
	375	60	840													
	377	75	1050													
65H	525	30	300		PULLEY	322	ROLLER	9.44886	4.33072	1.96851	1.96851			4.3309 4.3314	"	9.4495 9.4505
	591	45	400													
	583	50	450													
	570	65	600		COMM	317	BALL	7.08664	3.34647	1.61418	1.61418			3.3467 3.3472	"	7.0870 7.0880
	547	75	720													
	467	80	900													
	583	100	900													
80H	700	40	300		PULLEY	322	ROLLER	9.44886	4.33072	1.96851	1.96851			4.3309 4.3314	"	9.4495 9.4505
	723	55	400													
	700	60	450													
	700	80	600		COMM	317	BALL	7.08664	3.34647	1.61418	1.61418			3.3467 3.3472	"	7.0870 7.0880
	657	90	720													
	700	120	900													
81H	543	30	290		PULLEY	322	ROLLER	9.44886	4.33072	1.96851	1.96851			4.3309 4.3314	"	9.4495 9.4505
	656	55	440													
	700	80	600													
	730	125	900		COMM	317	BALL	7.08664	3.34647	1.61418	1.61418			3.3467 3.3472	"	7.0870 7.0880
	700	150	1125													
	672	160	1250													
101H	793	40	265		PULLEY	326	ROLLER	11.0236	5.1181	2.2835	2.2835			5.1183 5.1188	"	11.0260 11.0270
	950	75	415													
	457	100	550													
	892	140	825		COMM	320	BALL	8.4646	3.9370	1.8504	1.8504			3.9372 3.9377	"	8.4650 8.4660
	960	150	825													
	934	200	1125													
125H	1350	55	215		PULLEY	326	ROLLER	11.0236	5.1181	2.2835	2.2835			5.1183 5.1188	"	11.0260 11.0270
	1320	60	240													
	1290	80	325													
	1315	125	500		COMM	320	BALL	8.4646	3.9370	1.8504	1.8504			3.9372 3.9377	"	8.4650 8.4660
	1300	165	670													
	1150	175	800													
151H	1430	65	240		PULLEY	332	ROLLER	13.3858	6.2992	2.6772	2.6772			6.2995 6.3000	"	13.3880 13.3890
	1620	100	325													
	1680	135	425													
	1850	175	500		COMM	324	BALL	10.2362	4.7244	2.1654	2.1654			4.7246 4.7251	"	10.2370 10.2380
	1690	225	700													
	1750	300	900													

SEE TABLE A1 FOR A-B-C SKETCH OF ROLLER BEARING

TABLE C-13

CROCKER WHEELER A. C. MOTORS

MOTOR DATA				BEARING DATA												
FRAME	TORQUE	H.P.	R.P.M	M'F'G.	S.A.E. BEARING SIZE		TYPE	A	B	C	D	BALLS Nº	BALLS DIA.	SHAFT DIA.	CART'G O.D.	FRAME BORE
5R	35	5	750		PULLEY	311	BALL	4.72443	2.16536	1.14173	1.14173			2.1656 2.1661	NONE	4.7250 4.7260
					O.E.	311	"	4.72443	2.16536	1.14173	1.14173			2.1656 2.1661	"	4.7250 4.7260
7½R	52.5	7½	750		PULLEY	311	"	4.72443	2.16536	1.14173	1.14173			2.1656 2.1661	"	4.7250 4.7260
					O.E.	311	"	4.72443	2.16536	1.14173	1.14173			2.1656 2.1661	"	4.7250 4.7260
10R	70	10	750		PULLEY	315	"	6.29924	2.95277	1.45669	1.45669			2.9530 2.9535	"	6.3000 6.3010
					O.E.	315	"	6.29924	2.95277	1.45669	1.45669			2.9530 2.9535	"	6.3000 6.3010
15R	105	15	750		PULLEY	315	"	6.29924	2.95277	1.45669	1.45669			2.9530 2.9535	"	6.3000 6.3010
					O.E.	315	"	6.29924	2.95277	1.45669	1.45669			2.9530 2.9535	"	6.3000 6.3010
20R	140	20	750		PULLEY	318	"	7.48035	3.54332	1.69292	1.69292			3.5435 3.5440	"	7.4810 7.4820
					O.E.	318	"	7.48035	3.54332	1.69292	1.69292			3.5435 3.5440	"	7.4810 7.4820
25R	175	25	750		PULLEY	318	"	7.48035	3.54332	1.69292	1.69292			3.5435 3.5440	"	7.4810 7.4820
					O.E.	318	"	7.48035	3.54332	1.69292	1.69292			3.5435 3.5440	"	7.4810 7.4820
35R	210	20	500		PULLEY	320	"	8.46460	3.93702	1.85040	1.85040			3.9372 3.9377	"	8.4650 8.4660
	245	35	750		O.E.	320	"	8.46460	3.93702	1.85040	1.85040			3.9372 3.9377	"	8.4650 8.4660
50R	367	35	500		PULLEY	322	"	9.44886	4.33072	1.96851	1.96851			4.3309 4.3314	"	9.4495 9.4505
	350	50	750		O.E.	322	"	9.44886	4.33072	1.96851	1.96851			4.3309 4.3314	"	9.4495 9.4505
51R	525	50	500		PULLEY	319	ROLLER	7.87405	3.74017	1.77166	1.77166			3.7404 3.7409	"	7.8750 7.8760
	525	75	750		O.E.	319	"	7.87405	3.74017	1.77166	1.77166			3.7404 3.7409	"	7.8750 7.8760
75R	787	75	500		PULLEY	321	"	8.85830	4.13387	1.92914	1.92914			4.1341 4.1346	"	8.8590 8.8600
	700	100	750		O.E.	321	"	8.85830	4.13387	1.92914	1.92914			4.1341 4.1346	"	8.8590 8.8600
100R	1050	75	375		PULLEY	326	"	11.0236	5.1181	2.2835	2.2835			5.1183 5.1188	"	11.0260 11.0270
	1050	100	500													
	1050	150	750		O.E.	326	"	11.0236	5.1181	2.2835	2.2835			5.1183 5.1188	"	11.0260 11.0270
150R	1400	100	375		PULLEY	326	"	11.0236	5.1181	2.2835	2.2835			5.1183 5.1188	"	11.0260 11.0270
	1575	150	500													
	1450	200	750		O.E.	326	"	11.0236	5.1181	2.2835	2.2835			5.1183 5.1188	"	11.0260 11.0270
200R	2100	150	375		PULLEY	332	"	13.3858	6.2992	2.6772	2.6772			6.2995 6.3000	"	13.3880 13.3890
	2100	200	500		O.E.	332	"	13.3858	6.2992	2.6772	2.6772			6.2995 6.3000	"	13.3880 13.3890
250R	2800	200	375		PULLEY	332	"	13.3858	6.2992	2.6772	2.6772			6.2995 6.3000	"	13.3880 13.3890
	2625	250	500		O.E.	332	"	13.3858	6.2992	2.6772	2.6772			6.2995 6.3000	"	13.3880 13.3890

·25 CYCLE MOTORS

SEE TABLE A1 FOR A-B-C SKETCH OF ROLLER BEARING

TABLE C-14

CROCKER WHEELER A.C MOTORS

MOTOR DATA				BEARING DATA											
FRAME	TORQUE	H.P.	R.P.M.	M'F'G.	S.A.E. BEARING SIZE	TYPE	A	B	C	D	ROLLER Nº	ROLLER DIA.	SHAFT DIA.	CARTG O.D.	FRAME BORE
22Q	306	35	600		PULLEY 322	BALL	9.4498	4.3307	1.9685	1.9685			4.3309 4.3314	NONE	9.4495 9.4505
	292	40	720												
	365	50	720		O.E. 322	"	9.4488	4.3307	1.9685	1.9685			4.3309 4.3314	"	9.4495 9.4505
	350	60	900												
	330	75	1200												
23Q	356	35	514		PULLEY 319	ROLLER	7.8740	3.7402	1.7717	1.7717			3.7404 3.7409	"	7.8750 7.8760
	438	50	600												
	437	60	720		O.E. 319	"	7.8740	3.7402	1.7717	1.7717			3.7404 3.7409	"	7.8750 7.8760
	438	75	900												
24Q	510	50	514		PULLEY 321	"	8.8583	4.1339	1.9291	1.9291			4.1341 4.1346	"	8.8590 8.8600
	525	60	600												
	547	75	720		O.E. 321	"	8.8583	4.1339	1.9291	1.9291			4.1341 4.1346	"	8.8590 8.8600
	583	100	900												
25Q	659	75	600		PULLEY 321	"	8.8583	4.1339	1.9291	1.9291			4.1341 4.1346	"	8.8590 8.8600
	788	100	720												
	915	125	720		O.E. 321	"	8.8583	4.1339	1.9291	1.9291			4.1341 4.1346	"	8.8590 8.8600
	730	125	900												
25AQ	878	75	450		PULLEY 326	"	11.0236	5.1181	2.2835	2.2835			5.1183 5.1188	"	11.0260 11.0270
	1020	100	514												
	1100	125	600		O.E. 326	"	11.0236	5.1181	2.2835	2.2835			5.1183 5.1188	"	11.0260 11.0270
	1190	150	720												
	1165	200	900												
26Q	985	75	400		PULLEY 328	"	11.8110	5.5118	2.4409	2.4409			5.5120 5.5125	"	11.8140 11.8150
	1170	100	450												
	1460	125	450												
	1280	125	514		O.E. 328	"	11.8110	5.5118	2.4409	2.4409			5.5120 5.5125	"	11.8140 11.8150
	1320	150	600												
	1460	200	720												
27Q	1640	125	400		PULLEY 332	"	13.3858	6.2992	2.6772	2.6772			6.2995 6.3000	"	13.3880 13.3890
	1760	150	450												
	1790	175	514		O.E. 332	"	13.3858	6.2992	2.6772	2.6772			6.2995 6.3000	"	13.3880 13.3890
	1760	200	600												
28Q	2300	175	400		PULLEY 332	"	13.3858	6.2992	2.6772	2.6772			6.2995 6.3000	"	13.3880 13.3890
	2330	200	450												
	2560	250	514		O.E. 332	"	13.3858	6.2992	2.6772	2.6772			6.2995 6.3000	"	13.3880 13.3890
	2530	300	600												

60 CYCLE MOTORS

SEE TABLE A1 FOR A-B-C SKETCH OF ROLLER BEARING

TABLE C-15

ELLIOTT A.C. MOTORS

MOTOR DATA				BEARING DATA											
FRAME	TORQUE	H.P.	R.P.M	M'F'G.	S.A.E. BEARING SIZE	TYPE	A	B	C	D	ROLLER Nº	ROLLER DIA.	SHAFT DIA.	CART'G O.D.	FRAME BORE
154	59.8	20	1760	TIMKEN	PULLEY 8309	ROLLER	3.9362 3.9370	1.7712 1.7717	1.5625	1.5625	32	.484			
					O.E. 8309	"	3.9362 3.9370	1.7712 1.7717	1.5625	1.5625	32	.484			
156	74.6	25	1760	"	PULLEY 8309	"	3.9362 3.9370	1.7712 1.7717	1.5625	1.5625	32	.484			
					O.E 8309	"	3.9362 3.9370	1.7712 1.7717	1.5625	1.5625	32	.484			
193	89.4	20	1170	"	PULLEY 8311	"	4.7236 4.7244	2.1649 2.1654	1.9375	1.9375	32	.594			
					O.E. 8311	"	4.7236 4.7244	2.1649 2.1654	1.9375	1.9375	32	.594			
194	121	20	865	"	PULLEY 8311	"	4.7236 4.7244	2.1649 2.1654	1.9375	1.9375	32	.594			
	112	25	1170												
	895	30	1760		O.E. 8311	"	4.7236 4.7244	2.1649 2.1654	1.9375	1.9375	32	.594			
195	151	20	695	"	PULLEY 8311	"	4.7236 4.7244	2.1649 2.1654	1.9375	1.9375	32	.594			
	152	25	865												
	134	30	1170		O.E. 8311	"	4.7236 4.7244	2.1649 2.1654	1.9375	1.9375	32	.594			
	1195	40	1760												
196	183	20	575	"	PULLEY 8311	"	4.7236 4.7244	2.1649 2.1654	1.9375	1.9375	32	.594			
	189	25	695												
	182	30	865												
	179	40	1170		O.E. 8311	"	4.7236 4.7244	2.1649 2.1654	1.9375	1.9375	32	.594			
	149	50	1760												
225	228	25	575	"	PULLEY 8314	"	5.9043 5.9055	2.7553 2.7559	2.5000	2.5000	28	.812			
	227	30	695												
	243	40	865												
	224	50	1170		O.E. 8314	"	5.9043 5.9055	2.7553 2.7559	2.5000	2.5000	28	.812			
	179	60	1760												
226	274	30	575	"	PULLEY 8314	"	5.9043 5.9055	2.7553 2.7559	2.5000	2.5000	28	.812			
	303	40	695												
	304	50	865												
	268	60	1170		O.E. 8314	"	5.9043 5.9055	2.7553 2.7559	2.5000	2.5000	28	.812			
	224	75	1760												
228	365	40	575	"	PULLEY 8314	"	5.9043 5.9055	2.7553 2.7559	2.5000	2.5000	28	.812			
	378	50	695		O.E. 8314	"	5.9043 5.9055	2.7553 2.7559	2.5000	2.5000	28	.812			
255	364	60	865	"	PULLEY 8318	"	7.4791 7.4803	3.5426 3.5433	2.8750	2.8750	28	1.031			
	335	75	1170												
	298	100	1760		O.E. 8318	"	7.4791 7.4803	3.5426 3.5433	2.8750	2.8750	28	1.031			
256	467	50	575	"	PULLEY 8318	"	7.4791 7.4803	3.5426 3.5433	2.8750	2.8750	28	1.031			
	453	60	695												
	455	75	865												
	447	100	1170		O.E. 8318	"	7.4791 7.4803	3.5426 3.5433	2.8750	2.8750	28	1.031			
	373	125	1760												
258	548	60	575	"	PULLEY 8318	"	7.4791 7.4803	3.5426 3.5433	2.8750	2.8750	28	1.031			
	567	75	695												
	607	100	865												
	560	125	1170		O.E. 8318	"	7.4791 7.4803	3.5426 3.5433	2.8750	2.8750	28	1.031			
	448	150	1760												
286	685	75	575	"	PULLEY 8322	"	9.4477 9.4489	4.3300 4.3307	3.6250	3.6250	28	1.25			
	756	100	695												
	760	125	865		O.E. 8322	"	9.4477 9.4489	4.3300 4.3307	3.6250	3.6250	28	1.25			
	670	150	1170												
288	913	100	575	"	PULLEY 8322	"	9.4477 9.4489	4.3300 4.3307	3.6250	3.6250	28	1.25			
	945	125	695												
	910	150	865		O.E. 8322	"	9.4477 9.4489	4.3300 4.3307	3.6250	3.6250	28	1.25			
2810	1140	125	575	"	PULLEY 8322	"	9.4477 9.4489	4.3300 4.3307	3.6250	3.6250	28	1.25			
	1135	150	695												
	1210	200	865		O.E. 8322	"	9.4477 9.4489	4.3300 4.3307	3.6250	3.6250	28	1.25			
328	1220	100	430	"	PULLEY 8322	"	9.4477 9.4489	4.3300 4.3307	3.6250	3.6250	28	1.25			
	1370	150	575												
	1510	200	695		O.E. 8322	"	9.4477 9.4489	4.3300 4.3307	3.6250	3.6250	28	1.25			
3210	1525	125	430	"	PULLEY 8322	"	9.4477 9.4489	4.3300 4.3307	3.6250	3.6250	28	1.25			
	1830	200	575		O.E. 8322	"	9.4477 9.4489	4.3300 4.3307	3.6250	3.6250	28	1.25			
3212	1830	150	430	"	PULLEY 8322	"	9.4477 9.4489	4.3300 4.3307	3.6250	3.6250	28	1.25			
					O.E 8322	"	9.4477 9.4489	4.3300 4.3307	3.6250	3.6250	28	1.25			

SEE TABLE-A1 FOR A-B-C SKETCH FOR ROLLER BEARING.

TABLE C-16

ELECTRO DYNAMIC A.C. MOTORS

MOTOR DATA				BEARING DATA											
FRAME	TORQUE	H.P.	R.P.M.	M'F'G.	S.A.E. BEARING SIZE		TYPE	A	B	C	D	BALLS Nº	BALLS DIA.	SHAFT DIA.	CART'G O.D.	FRAME BORE
82A	4.5	1	1750		PULLEY	305	BALL	2.4409	.9843	.6693	.6693		.375	.9843 .9848		2.4414 2.4419
					O.E.	304	"	2.0472	.7874	.5906	.5906		.3125	.7874 .7879		2.0477 2.0482
91A	6.75	1½	1750		PULLEY	306	"	2.8346	1.1811	.7480	.7480		.4375	1.1811 1.1816		2.8351 2.8356
					O.E.	305	"	2.4409	.9843	.6693	.6693		.375	.9843 .9848		2.4414 2.4419
92A	9	2	1750		PULLEY	306	"	2.8346	1.1811	.7480	.7480		.4375	1.1811 1.1816		2.8351 2.8356
					O.E.	305	"	2.4409	.9843	.6693	.6693		.375	.9843 .9848		2.4414 2.4419
110BA	13.5	3	1750		PULLEY	306	"	2.8346	1.1811	.7480	.7480		.4375	1.1811 1.1816		2.8351 2.8356
					O.E.	305	"	2.4409	.9843	.6693	.6693		.375	.9843 .9848		2.4414 2.4419
112BA	22.5	5	1750		PULLEY	307	"	3.1496	1.3780	.8268	.8268		.500	1.3780 1.3785		3.1501 3.1506
					O.E.	306	"	2.8346	1.1811	.7480	.7480		.4375	1.1811 1.1816		2.8351 2.8356
130BA	34	7½	1750		PULLEY	308	"	3.5433	1.5748	.9055	.9055		.5625	1.5749 1.5754		3.5438 3.5443
					O.E.	307	"	3.1496	1.3780	.8268	.8268		.500	1.3780 1.3785		3.1501 3.1506
131BA	45	10	1750		PULLEY	310	"	4.3307	1.9685	1.0630	1.0630		.6875	1.9686 1.9691		4.3312 4.3317
					O.E.	308	"	3.5433	1.5748	.9055	.9055		.5625	1.5749 1.5754		3.5438 3.5443
132BA	67.5	15	1750		PULLEY	310	"	4.3307	1.9685	1.0630	1.0630		.6875	1.9686 1.9691		4.3312 4.3317
					O.E.	308	"	3.5433	1.5748	.9055	.9055		.5625	1.5749 1.5754		3.5438 3.5443
160BA	90	20	1750		PULLEY	312	"	5.1181	2.3622	1.2205	1.2205		.8125	2.3624 2.3629		5.1186 5.1191
					O.E.	310	"	4.3307	1.9685	1.0630	1.0630		.6875	1.9686 1.9691		4.3312 4.3317
161BA	112.5	25	1750		PULLEY	312	"	5.1181	2.3622	1.2205	1.2205		.8125	2.3624 2.3629		5.1186 5.1191
					O.E.	310	"	4.3307	1.9685	1.0630	1.0630		.6875	1.9686 1.9691		4.3312 4.3317
162BA	135	30	1750		PULLEY	313	"	5.5118	2.5591	1.2992	1.2992		.875	2.5593 2.5598		5.5123 5.5128
					O.E.	310	"	4.3307	1.9685	1.0630	1.0630		.6875	1.9686 1.9691		4.3312 4.3317
172B	180	40	1750		PULLEY	315	"	6.2992	2.9528	1.4567	1.4567		1.00	2.9530 2.9535		6.3002 6.3007
					O.E.	313	"	5.5118	2.5591	1.2992	1.2992		.875	2.5593 2.5598		5.5123 5.5128
173B	206	50	1750		PULLEY	315	"	6.2992	2.9528	1.4567	1.4567		1.00	2.9530 2.9535		6.3002 6.3007
					O.E.	313	"	5.5118	2.5591	1.2992	1.2992		.875	2.5593 2.5598		5.5123 5.5128
191B	274	60	1750		PULLEY	317	"	7.0866	3.3465	1.6142	1.6142		1.125	3.3468 3.3473		7.0876 7.0881
					O.E.	315	"	6.2992	2.9528	1.4567	1.4567		1.00	2.9530 2.9535		6.3002 6.3007
192B	343	75	1750		PULLEY	317	"	7.0866	3.3465	1.6142	1.6142		1.125	3.3468 3.3473		7.0876 7.0881
					O.E.	315	"	6.2992	2.9528	1.4567	1.4567		1.00	2.9530 2.9535		6.3002 6.3007

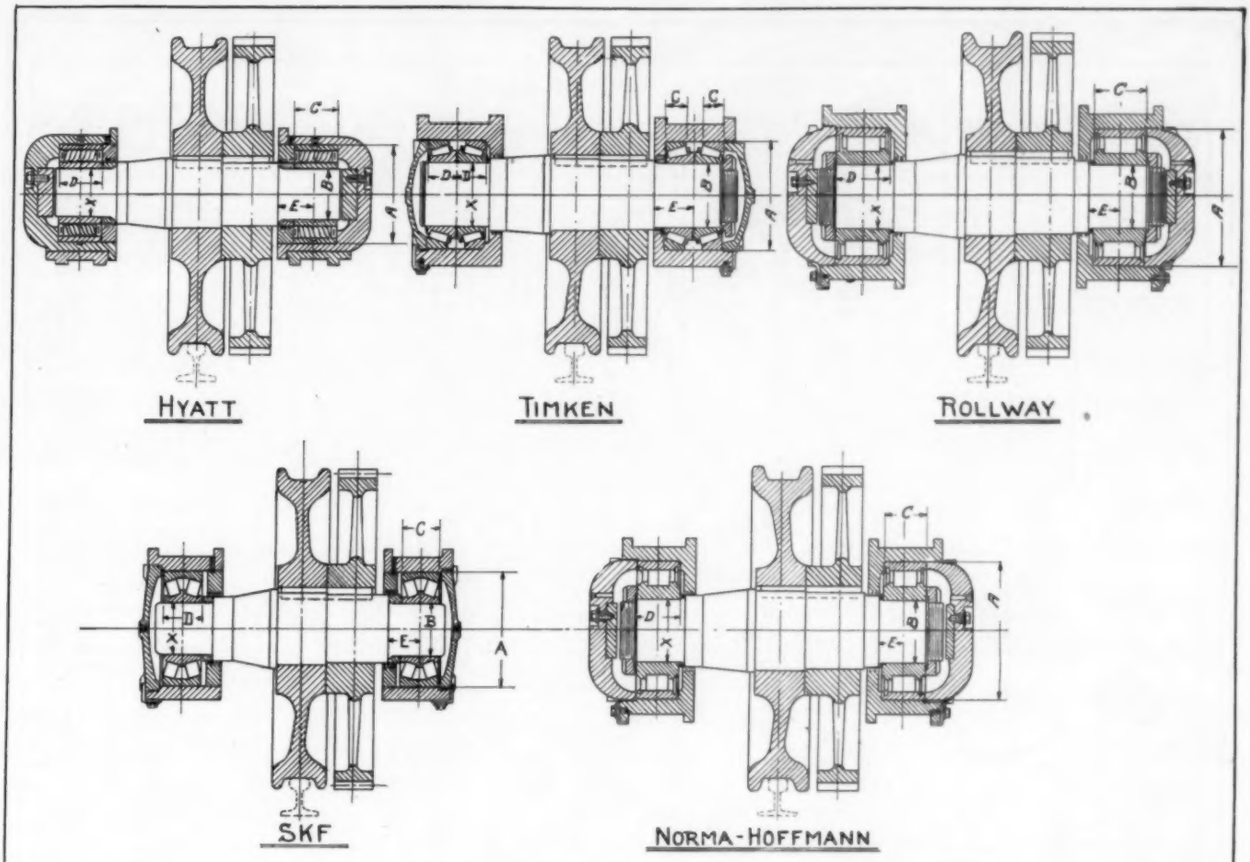
60 CYCLE MOTORS

TABLE C-17

ELECTRO DYNAMIC D.C. MOTORS

MOTOR DATA				BEARING DATA												
FRAME	TORQUE	H.P.	R.P.M	M'F'G.	S.A.E. BEARING	SIZE	TYPE	A	B	C	D	BALLS Nº	BALLS DIA.	SHAFT DIA.	CART'G O.D.	FRAME BORE
91E	4.5	1	1750		PULLEY	305	BALL	2.4409	.9843	.6693	.6693		.375	.9843 .9848		2.4414 2.4419
					COMM	304	"	2.0472	.7874	.5906	.5906		.3125	.7874 .7879		2.0477 2.0482
92E	6.75	1½	1750		PULLEY	306	"	2.8346	1.1811	.7480	.7480		.4375	1.1811 1.1816		2.8351 2.8356
					COMM	305	"	2.4409	.9843	.6693	.6693		.375	.9843 .9848		2.4414 2.4419
111E	9	2	1750		PULLEY	306	"	2.8346	1.1811	.7480	.7480		.4375	1.1811 1.1816		2.8351 2.8356
					COMM	305	"	2.4409	.9843	.6693	.6693		.375	.9843 .9848		2.4414 2.4419
½S	13.5	3	1750		PULLEY	306	"	2.8346	1.1811	.7480	.7480		.4375	1.1811 1.1816		2.8351 2.8356
					COMM	305	"	2.4409	.9843	.6693	.6693		.375	.9843 .9848		2.4414 2.4419
1S	22.5	5	1750		PULLEY	307	"	3.1496	1.3780	.8268	.8268		.500	1.3780 1.3785		3.1501 3.1506
					COMM	306	"	2.8346	1.1811	.7480	.7480		.4375	1.1811 1.1816		2.8351 2.8356
1SC	34	7½	1750		PULLEY	308	"	3.5433	1.5748	.9055	.9055		.5625	1.5749 1.5754		3.5438 3.5443
					COMM	307	"	3.1496	1.3780	.8268	.8268		.500	1.3780 1.3785		3.1501 3.1506
2S	45	10	1750		PULLEY	310	"	4.3307	1.9685	1.0630	1.0630		.6875	1.9686 1.9691		4.3312 4.3317
					COMM	308	"	3.5433	1.5748	.9055	.9055		.5625	1.5749 1.5754		3.5438 3.5443
3S	67.5	15	1750		PULLEY	310	"	4.3307	1.9685	1.0630	1.0630		.6875	1.9686 1.9691		4.3312 4.3317
					COMM	308	"	3.5433	1.5748	.9055	.9055		.5625	1.5749 1.5754		3.5438 3.5443
3S	90	20	1750		PULLEY	312	"	5.1181	2.3622	1.2205	1.2205		.8125	2.3624 2.3629		5.1186 5.1191
					COMM	310	"	4.3307	1.9685	1.0630	1.0630		.6875	1.9686 1.9691		4.3312 4.3317
5S	112.5	25	1750		PULLEY	312	"	5.1181	2.3622	1.2205	1.2205		.8125	2.3624 2.3629		5.1186 5.1191
					COMM	310	"	4.3307	1.9685	1.0630	1.0630		.6875	1.9686 1.9691		4.3312 4.3317
5S	135	30	1750		PULLEY	313	"	5.5118	2.5591	1.2992	1.2992		.875	2.5593 2.5598		5.5123 5.5128
					COMM	310	"	4.3307	1.9685	1.0630	1.0630		.6875	1.9686 1.9691		4.3312 4.3317
7½S	180	40	1750		PULLEY	315	"	6.2992	2.9528	1.4567	1.4567		1.00	2.9530 2.9535		6.3002 6.3007
					COMM	313	"	5.5118	2.5591	1.2992	1.2992		.875	2.5593 2.5598		5.5123 5.5128
10S	206	50	1750		PULLEY	315	"	6.2992	2.9528	1.4567	1.4567		1.00	2.9530 2.9535		6.3002 6.3007
					COMM	313	"	5.5118	2.5591	1.2992	1.2992		.875	2.5593 2.5598		5.5123 5.5128
10S	274	60	1750		PULLEY	317	"	7.0866	3.3465	1.6142	1.6142		1.125	3.3468 3.3473		7.0876 7.0881
					COMM	315	"	6.2992	2.9528	1.4567	1.4567		1.00	2.9530 2.9535		6.3002 6.3007
15S	343	75	1750		PULLEY	317	"	7.0866	3.3465	1.6142	1.6142		1.125	3.3468 3.3473		7.0876 7.0881
					COMM	315	"	6.2992	2.9528	1.4567	1.4567		1.00	2.9530 2.9535		6.3002 6.3007

TABLE C-18



MORGAN CRANE DATA

MAX. LOAD PER WHEEL	R.P.M.	WHEEL DIA.	BEARING M'F'G.	BEARING SIZE	A	B	C	D	E	X	ROLLER Nº	ROLLER DIA.	SHAFT DIA.	HOUSING BORE
18,000#	75	15"	HYATT	W-217	5.9076 5.9054	3.3468 3.3435	2.7500	2.7500	2.2500	2.5000	22	.625	3.3485 3.3474	5.9078 5.9052
			TIMKEN	759-752	5.9720 5.9720	3.4000 3.5010	1.5000	1.9000	2.7500	2.6250	34	.750		
			ROLLWAY	MF-5217	5.9055	3.3465	1.9375	1.9375	1.8750	2.3750	26	.5625	3.3478 3.3467	5.9055 5.9075
			S.K.F	22314	5.9055	2.7559	2.0080	2.0080	1.8750	2.3750	28	.870	2.7569 2.7561	5.9081 5.9055
			NORMA HOFFMAN	R-190-RR	6.2992	3.5433	1.1810	1.1810	1.5000	2.2500	27	.5625	3.5438 3.5433	6.2995 6.2985
25,000#	60	18"	HYATT	W-218	6.3008 6.2992	3.5276 3.5226	2.8125	2.8125	2.2500	2.7500	22	.6875	3.5454 3.5442	6.3011 6.2989
			TIMKEN	759-752	6.3750 6.3760	3.5000 3.5010	1.5000	1.9000	2.7500	2.8750	34	.750		
			ROLLWAY	MF-5219	6.6929	3.7402	2.1875	2.1875	2.0000	2.6250	26	.625	3.7412 3.7404	6.6965 6.6945
			S.K.F.	22315	6.2992	2.9528	2.1650	2.1650	2.0000	2.6250	28	.830	2.9538 2.9528	6.3018 6.2992
			NORMA HOFFMAN	R-200-RR	7.0866	3.9370	1.3390	1.3390	1.5000	2.3750	28	.625	3.9382 3.9372	7.0874 7.0854
30,000#	60	18"	HYATT	W-220	7.0883 7.0866	3.9373 3.9343	3.2500	3.2500	2.5000	3.0000	22	.750	3.9393 3.9380	7.0897 7.0863
			TIMKEN	861-854	7.5000 7.5010	4.0000 4.0010	1.7500	2.2650	3.1250	3.2500	34	.875		
			ROLLWAY	MF-5220	7.0866	3.9370	2.3750	2.3750	2.1250	2.8750	23	.750	3.9386 3.9374	7.0906 7.0886
			S.K.F.	22317	7.0866	3.3465	2.3620	2.3620	2.1250	2.8750	28	.980	3.3477 3.3465	7.0906 7.0866
			NORMA HOFFMAN	R-205-RR	7.4803	4.1339	1.4170	1.4170	1.6250	2.6250	24	.750	2.1357 2.1346	7.4811 7.4806
35,000#	60	18"	HYATT	W-222	7.8758 7.8740	4.3319 4.3292	3.5000	3.5000	2.7500	3.2500	21	.875	4.3337 4.3318	7.8769 7.8732
			TIMKEN	861-854	7.5000 7.5010	4.0000 4.0018	1.7500	2.2650	3.1250	3.3750	34	.875		
			ROLLWAY	MF-5221	7.4803	4.1339	2.5625	2.5625	2.2500	3.0000	24	.750	2.1349 2.1341	7.4851 7.4831
			S.K.F.	22318	7.4803	3.5433	2.5200	2.5200	2.2500	3.0000	28	1.060	3.5436 3.5433	7.4803 7.4803
			NORMA HOFFMAN	RLS-22-RR	8.0000	4.5000	1.3125	1.31250	1.7500	2.8750	26	.750	4.5012 4.5007	7.9995 7.9990
45,000#	50	24"	HYATT	W-222	7.8758 7.8740	4.3319 4.3292	3.5000	3.5000	2.7500	3.5000	21	.875	4.3337 4.3318	7.8769 7.8732
			TIMKEN	938-932	8.3750 8.3760	4.5000 4.5018	2.1250	2.6250	3.5000	3.8750	30	1.00		
			ROLLWAY	MF-5226	9.0552	5.1181	3.1250	3.1250	2.6250	3.5000	26	.875	5.1193 5.1183	9.0600 9.0579
			S.K.F.	22319	7.8740	3.7402	2.6370	2.6370	2.5000	3.5000	28	1.06	3.7414 3.7405	7.8768 7.8740
			NORMA HOFFMAN	RLS-23-RR	9.0000	5.0000	1.3750	1.3750	1.7500	3.0000	27	.8125	5.0012 5.0007	8.9995 8.9990
55,000#	50	24"	HYATT	W-226	9.0571 9.0551	5.1193 5.1173	4.2500	4.2500	3.2500	4.0000	21	1.00	5.1208 5.1193	9.0625 9.0546
			TIMKEN	95500-95925	9.5500 9.5510	5.0000 5.0010	1.9375	2.5000	3.5000	4.1250	34	1.00		
			ROLLWAY	MF-5226	9.0552	5.1181	3.1250	3.1250	2.6250	3.6250	26	.875	5.1193 5.1183	9.0600 9.0579
			S.K.F.	22322	9.4488	4.3307	3.1500	3.1500	2.6250	3.6250	28	1.380	4.3319 4.3310	9.4816 9.4788
			NORMA HOFFMAN	RLS-23½-RR	9.5000	5.5000	1.3750	1.3750	1.7500	3.2500	29	.8125	5.5012 5.5007	9.4995 9.4990
65,000#	40	27"	HYATT	W-226	9.0571 9.0551	5.1193 5.1173	4.2500	4.2500	3.2500	4.2500	21	1.00	5.1208 5.1193	9.0625 9.0546
			TIMKEN	95500-95925	9.5500 9.5510	5.0000 5.0010	1.9375	2.5000	3.5000	4.3750	34	1.00		
			ROLLWAY	MF-5230	10.6300	5.9055	3.5000	3.5000	2.7500	4.0000	26	1.00	5.9067 5.9057	10.6357 10.6329
			S.K.F.	22322	9.4488	4.3307	3.1500	3.1500	2.6250	3.8750	28	1.380	4.3319 4.3310	9.4816 9.4788
			NORMA HOFFMAN	RLS-24-RR	10.5000	6.0000	1.5625	1.5625	1.8750	3.5000	30	.875	6.0012 6.0007	10.4995 10.4990

TABLE-D1

MORGAN CRANE DATA

MAX. LOAD PER WHEEL	R.P.M	WHEEL DIA.	BEARING M'F'G.	BEARING SIZE	A	B	C	D	E	X	ROLLER Nº	ROLLER DIA	SHAFT DIA.	HOUSING BORE
75,000#	40	27"	HYATT	W-228	5.8445 5.8425	5.5122 5.5110	4.7500	4.7500	3.3750	4.500	22	1.0625	5.5148 5.5131	9.8451 9.8419
			TIMKEN	95525-95925	5.2500 5.2510	5.2500 5.2510	1.3375	2.500	3.500	4.500	34	1.000		
			ROLLWAY	MF 5230	10.6300	5.9055	3.500	3.500	2.750	4.250	26	1.000	5.9067 5.9057	10.6357 10.6329
			S.K.F.	22324	10.2362	4.7244	3.386	3.386	2.750	4.250	28	1.500	4.7256 4.7247	10.2320 10.2362
			NORMA HOFFMAN	RMS-24	12.000	6.0000	2.250	2.250	2.125	3.875	16	1.250	6.0012 6.0007	11.9985 11.9280
85,000#	40	27"	HYATT	W-232	11.4195 11.4173	6.2996 6.2983	4.875	4.875	3.500	4.750	21	1.250	6.3028 6.3006	11.4203 11.4166
			TIMKEN	99550-99100	10.0000 10.0010	5.5000 5.5010	1.875	2.625	3.625	4.750	38	1.000		
			ROLLWAY	MF-5232	11.4174	6.2992	3.875	3.875	3.000	4.500	25	1.125	6.3004 6.2994	11.4229 11.4201
			S.K.F.	22326	11.0236	5.1181	3.661	3.661	3.000	4.500	28	1.610	5.1192 5.1184	11.0248 11.0236
			NORMA HOFFMAN	RMS-24½	13.0000	6.5000	2.500	2.500	2.250	4.125	16	1.375	6.5014 6.5007	12.9985 12.9280
95,000#	40	27"	HYATT	W-234	12.2078 12.2047	6.6934 6.6920	5.375	5.375	3.750	5.000	21	1.375	6.6964 6.6944	12.2078 12.2039
			TIMKEN	94650-94113	11.3750 11.3760	6.3800 6.3810	1.875	2.500	3.500	4.875	46	1.000		
			ROLLWAY	MF-5232	11.4174	6.2992	3.875	3.875	3.000	4.625	25	1.125	6.3004 6.2994	11.4229 11.4201
			S.K.F	22328	11.8110	5.5118	4.016	4.016	3.125	4.625	28	1.730	5.5132 5.5121	11.8142 11.8110
			NORMA HOFFMAN	RMS-24½	13.0000	6.5000	2.500	2.500	2.250	4.250	16	1.375	6.5014 6.5007	12.9985 12.9280
100,000#	35	30"	HYATT	W-234	12.2078 12.2047	6.6934 6.6920	5.375	5.375	3.750	5.000	21	1.375	6.6964 6.6944	12.2078 12.2039
			TIMKEN	280625-281200	12.0000	6.2500	DOUBLE	CONE	3.250	4.875	38	1.250		
			ROLLWAY	MF-5232	11.4174	6.2992	3.8750	3.875	3.000	4.750	25	1.125	6.3004 6.2994	11.4229 11.4201
			S.K.F	22328	11.8110	5.5118	4.016	4.016	3.125	4.750	28	1.730	5.5132 5.5121	11.8142 11.8110
			NORMA HOFFMAN	RMS-25	13.5000	7.0000	2.5000	2.500	2.250	4.375	18	1.375	7.0012 7.0007	13.4985 13.4280
105,000#	35	30"	HYATT	W-236	12.6007 12.5984	7.0871 7.0857	5.8750	5.875	4.000	5.250	22	1.375	7.0902 7.0881	12.6017 12.5976
			TIMKEN	280625-281200	12.0000	6.2500	DOUBLE	CONE	3.250	5.000	38	1.250		
			ROLLWAY	MF-5234	12.2048	6.6929	4.1250	4.125	3.125	4.875	24	1.250	6.6941 6.6931	12.2103 12.2075
			S.K.F	22330	12.5984	5.9055	4.252	4.252	3.125	5.000	28	1.850	5.9068 5.9058	12.6016 12.5984
			NORMA HOFFMAN	RMS-25	13.5000	7.0000	2.5000	2.5000	2.250	4.500	18	1.375	7.0012 7.0007	13.4985 13.4280
110,000#	25	30"	HYATT	W-236	12.6007 12.5984	7.0871 7.0857	5.875	5.875	4.000	5.375	22	1.375	7.0902 7.0881	12.6017 12.5976
			TIMKEN	280700-281200	12.0000	7.0000	DOUBLE	CONE	3.250	5.000	38	1.250		
			ROLLWAY	MF-5234	12.2048	6.6929	4.1250	4.125	3.125	5.000	24	1.250	6.6941 6.6931	12.2103 12.2075
			S.K.F	22330	12.5984	5.9055	4.252	4.252	3.250	5.000	28	1.850	5.9068 5.9058	12.6016 12.5984
			NORMA HOFFMAN	RMS-25	13.5000	7.0000	2.500	2.500	2.250	4.500	18	1.375	7.0012 7.0007	13.4985 13.4280
120,000#	25	30"	HYATT	W-236	12.6007 12.5984	7.0871 7.0857	5.875	5.875	4.000	5.500	22	1.375	7.0902 7.0881	12.6017 12.5976
			TIMKEN	280700-281200	12.0000	7.0000	DOUBLE	CONE	3.250	5.250	38	1.250		
			ROLLWAY	MF-5236	12.5985	7.0866	4.250	4.250	3.125	5.125	25	1.250	7.0878 7.0868	12.6040 12.6012
			S.K.F.	22332	13.3858	6.2992	4.488	4.488	3.250	5.250	28	1.970	6.3005 6.2995	13.3890 13.3858
			NORMA HOFFMAN	RMS-25½	14.5000	7.5000	2.750	2.750	2.500	4.750	18	1.500	7.5012 7.5007	14.4985 14.4280
125,000#	25	30"	HYATT	SW-240	13.3863 13.3858	7.8743 7.8730	6.875	6.875	4.500	6.000	24	1.375	7.8792 7.8776	13.3890 13.3858
			TIMKEN	280700-281200	12.0000	7.0000	DOUBLE	CONE	3.250	5.250	38	1.250		
			ROLLWAY	MF-5236	12.5985	7.0866	4.250	4.250	3.125	5.250	25	1.250	7.0878 7.0868	12.6040 12.6012
			S.K.F	22332	13.3858	6.2992	4.488	4.488	3.250	5.250	28	1.970	6.3005 6.2995	13.3890 13.3858
			NORMA HOFFMAN	RMS-25½	14.5000	7.5000	2.750	2.750	2.500	4.750	18	1.500	7.5012 7.5007	14.4985 14.4280
130,000#	25	30"	HYATT	SW-240	13.3863 13.3858	7.8743 7.8730	6.875	6.875	4.500	6.000	24	1.375	7.8792 7.8776	13.3890 13.3858
			TIMKEN	210750-211300	13.0000	7.5000	DOUBLE	CONE	3.250	5.250	42	1.250		
			ROLLWAY	MF-5238	13.3859	7.4804	4.500	4.500	3.250	5.250	24	1.375	7.4818 7.4806	13.3914 13.3886
			S.K.F	22332	13.3858	6.2992	4.488	4.488	3.250	5.250	28	1.970	6.3006 6.2995	13.3890 13.3858
			NORMA HOFFMAN	RMS-25½	14.5000	7.5000	2.750	2.750	2.500	4.750	18	1.500	7.5012 7.5007	14.4985 14.4280

TIMKEN TOLERANCES

BEARING	SHAFT FLOATING END	HOUSING FLOATING END	SHAFT TIGHT END	HOUSING TIGHT END
759-752	3.5010 3.5000	6.3770 6.3750	3.5030 3.5020	6.3770 6.3750
861-854	4.0010 4.0000	7.5020 7.5000	4.0030 4.0020	7.5020 7.5000
938-932	4.5010 4.5000	8.3770 8.3750	4.5030 4.5020	8.3770 8.3750
95500-95925	5.0010 5.0000	9.2520 9.2500	5.0040 5.0030	9.2520 9.2500
99550-99100	5.5010 5.5000	10.0020 10.0000	5.5040 5.5030	10.0020 10.0000
94650-94113	6.5010 6.5000	11.3770 11.3750	6.5040 6.5030	11.3770 11.3750
280625-281200	6.2510 6.2500	12.0030 12.0010	6.2540 6.2530	12.0030 12.0010
280700-281200	7.0010 7.0000	12.0030 12.0010	7.0060 7.0040	12.0030 12.0010
210750-211300	7.5010 7.5000	13.0030 13.0010	7.5050 7.5040	13.0030 13.0010
95525-95525	5.2510 5.2500	9.2520 9.2500	5.2540 5.2530	9.2520 9.2500

NOTE:-

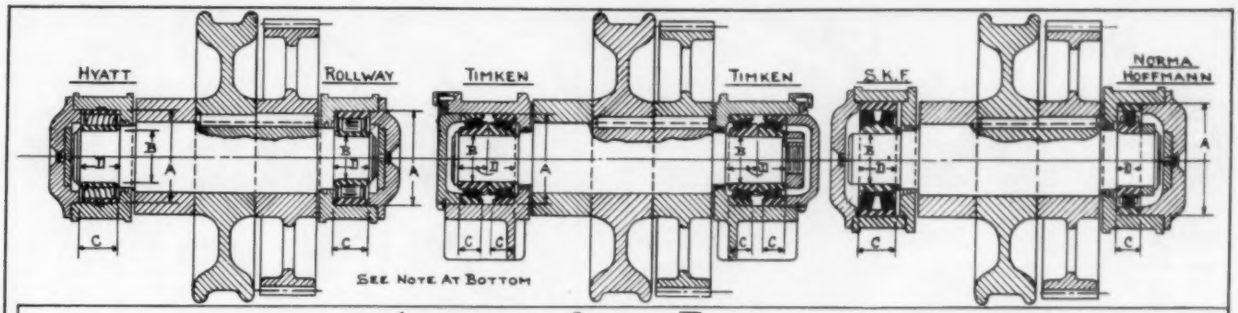
BEARING SIZES SHOWN IN TABULATION ARE BASED ON BEARINGS BEING SYMMETRICAL ABOUT CENTER OF TRACKWHEEL TREAD.

AXLES ARE TO BE STEEL FORGINGS, .30 TO .40 CARBON, 74,000 LBS. TENSILE STRENGTH.

DESIGN TO BE BASED ON SAFETY FACTOR OF 5

BEARING DIAMETERS FOR 14,800 LBS. PER SQ. IN. MAXIMUM NECK STRESS ARE SHOWN FOR COMPARISON ONLY UNDER COLUMN HEADED "X".

TABLE-D1a

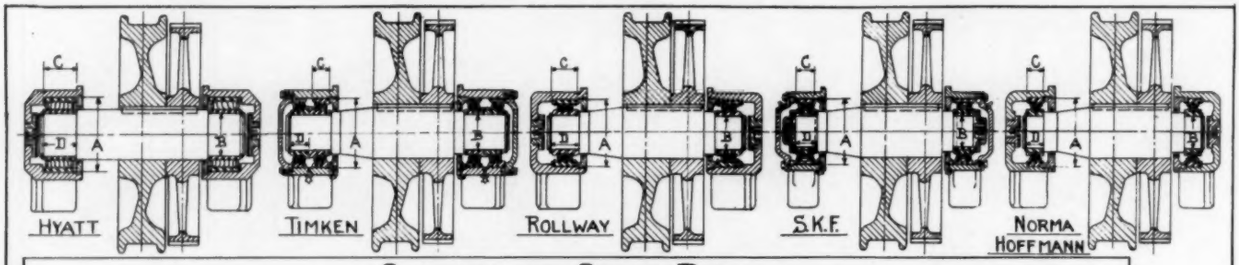


ALLIANCE CRANE DATA

MAX LOAD PER WHEEL	R.P.M.	WHEEL DIA.	BEARING MFG.	BEARING SIZE	A	B	C	D	ROLLER No.	ROLLER DIA.	SHAFT DIA.	HOUSING BORE	SHAFT DIA FLOATING END
15,000#	125	18"	HYATT	W-215	5.1185 5.1181	2.9530 2.9527	2.625	2.625	24	.500	2.9542 2.9537	5.1187 5.1181	
			TIMKEN	577-572	5.5115	2.9375	1.1250	1.4212	38	.625	2.9395 2.9390	5.5128 5.5118	2.9375 2.9397
			ROLLWAY	MF-5312	5.1181 5.1177	2.3622 2.3616	2.1250	2.1250	20	.593	2.3639 2.3634	5.1221 5.1201	
			S.K.F.	22312	5.1181	2.3622	1.8110	1.8110	28	.748	2.3632 2.3624	5.1207 5.1181	
			NORMA HOFFMANN	R-360	5.1181	2.3622	1.2200	1.2200	12	.625	2.3627 2.3622	5.1193 5.1174	
22,500#	100	18"	HYATT	W-217	5.5070 5.5055	3.3466 3.3458	2.7500	2.7500	22	.625	3.3485 3.3474	5.5073 5.5052	
			TIMKEN	749-742	5.9090	3.3475	1.4375	1.8375	32	.750	3.3485 3.3480	5.9100 5.9080	3.3475 3.3485
			ROLLWAY	MF-5314	5.5055 5.5045	2.7559 2.7553	2.5000	2.5000	22	.625	2.7569 2.7561	5.5085 5.5075	
			S.K.F.	22314	5.9055	2.7559	2.0080	2.0080	28	.866	2.7569 2.7561	5.5081 5.5065	
			NORMA HOFFMANN	R-370	5.9055	2.7559	1.3780	1.3780	15	.625	2.7569 2.7561	5.9053 5.9039	
30,000#	100	18"	HYATT	W-220	7.0883 7.0866	3.3478 3.3465	3.2500	3.2500	22	.750	3.3490 3.3480	7.0886 7.0869	
			TIMKEN	780-772	7.1250	4.0000	1.5000	1.8900	36	.750	4.0030 4.0020	7.1270 7.1250	4.0000 4.0010
			ROLLWAY	MF-5220	7.0866 7.0852	3.3570 3.3562	2.3750	2.3750	23	.750	3.3580 3.3570	7.0886 7.0866	
			S.K.F.	22317	7.0866	3.3465	2.3620	2.3620	28	.9843	3.3477 3.3468	7.0892 7.0866	
			NORMA HOFFMANN	R.385	7.0866	3.3465	1.6140	1.6140	14	.875	3.3477 3.3470	7.0866 7.0846	
48,000#	75	18"	HYATT	W-224	8.4653 8.4642	4.7247 4.7236	3.8750	3.8750	21	.9375	4.7271 4.7256	8.4670 8.4642	
			TIMKEN	938-932	8.3750	4.5000	2.1250	2.6250	30	1.000	4.5030 4.5020	8.3760 8.3740	4.5000 4.5010
			ROLLWAY	MF-5224	8.4653 8.4634	4.7247 4.7236	3.0000	3.0000	28	.750	4.7256 4.7236	8.4654 8.4626	
			S.K.F.	22320	8.4646	3.9370	2.8740	2.8740	28	1.220	3.9382 3.9378	8.4674 8.4646	
			NORMA HOFFMANN	R.-400	8.4646	3.9370	1.8500	1.8500	14	1.000	3.9382 3.9380	8.4644 8.4626	
30,000#	75	24"	HYATT	W-220	7.0883 7.0866	3.3478 3.3465	3.2500	3.2500	22	.750	3.3490 3.3480	7.0886 7.0869	
			TIMKEN	780-772	7.1250	4.0000	1.5000	1.8900	36	.750	4.0030 4.0020	7.1270 7.1250	4.0000 4.0010
			ROLLWAY	MF-5220	7.0866 7.0852	3.3570 3.3562	2.3750	2.3750	23	.750	3.3580 3.3570	7.0886 7.0866	
			S.K.F.	22317	7.0866	3.3465	2.3620	2.3620	28	.9843	3.3477 3.3468	7.0892 7.0866	
			NORMA HOFFMANN	R-385	7.0866	3.3465	1.6140	1.6140	14	.875	3.3477 3.3470	7.0864 7.0838	
52,500#	60	24"	HYATT	W-224	8.4653 8.4642	4.7247 4.7236	3.8750	3.8750	21	.9375	4.7271 4.7256	8.4670 8.4642	
			TIMKEN	938-932	8.3750	4.5000	2.1250	2.6250	30	1.000	4.5030 4.5020	8.3760 8.3740	4.5000 4.5010
			ROLLWAY	MF-5224	8.4653 8.4634	4.7247 4.7236	3.0000	3.0000	28	.750	4.7256 4.7236	8.4654 8.4626	
			S.K.F.	22320	8.4646	3.9370	2.8740	2.8740	28	1.22	3.9382 3.9378	8.4674 8.4646	
			NORMA HOFFMANN	R-400	8.4646	3.9370	1.8500	1.8500	14	1.000	3.9382 3.9380	8.4644 8.4626	
75,000#	50	24"	HYATT	W-228	8.8445 8.8425	5.5122 5.5110	4.7500	4.7500	22	1.0625	5.5138 5.5131	8.8451 8.8419	
			TIMKEN	99600-99100	10.0000	6.0000	1.8750	2.6250	38	1.000	6.0035 6.0040	10.0020 10.0000	6.0000 6.0010
			ROLLWAY	MF-5226	8.0551 8.0539	5.1181 5.1171	3.1250	3.1250	26	.875	5.1193 5.1185	8.0609 8.0576	
			S.K.F.	22324	10.2362	4.7244	3.3860	3.3860	28	1.500	4.7256 4.7244	10.2390 10.2342	
			NORMA HOFFMANN	RMS-23	10.0000	5.0000	2.0000	2.0000	16	1.125	5.0007 5.0012	10.0085 9.9980	
65,000#	50	27"	HYATT	W-226	9.0571 9.0551	5.1185 5.1177	4.2500	4.2500	21	1.00	5.1205 5.1193	9.0594 9.0564	
			TIMKEN	95500-95925	9.2500	5.0000	1.9375	2.5000	34	1.00	5.0035 5.0040	9.2520 9.2500	5.0000 5.0010
			ROLLWAY	MF-5226	8.0551 8.0539	5.1181 5.1171	3.1250	3.1250	26	.875	5.1193 5.1185	8.0609 8.0576	
			S.K.F.	22322	9.4488	4.3307	3.1500	3.1500	28	1.378	4.3315 4.3310	9.4516 9.4488	
			NORMA HOFFMANN	R-405	8.8583	4.1339	1.9290	1.9290	16	1.000	4.1344 4.1339	8.8587 8.8556	
90,000#	40	27"	HYATT	W-232	11.4185 11.4173	6.2996 6.2583	4.8750	4.8750	21	1250	6.3025 6.3005	11.4209 11.4166	
			TIMKEN	94650-94113	11.3750	6.5000	1.8750	2.5000	46	1.000	6.5030 6.5020	11.3770 11.3750	6.5000 6.5010
			ROLLWAY	MF-5230	10.0394 10.0383	5.5133 5.5045	3.5000	3.5000	26	1.000	5.5057 5.5047	10.0427 10.0379	
			S.K.F.	22328	11.8110	5.5118	4.0160	4.0160	28	1.730	5.5127 5.5118	11.8140 11.8110	
			NORMA HOFFMANN	RMS-23½	11.0000	5.5000	2.0000	2.0000	17	1.125	5.5007 5.5012	10.9985 10.9980	
115,000#	40	27"	HYATT	W-236	12.4997 12.4984	7.0871 7.0857	5.8750	5.8750	22	1.375	7.0882 7.0861	12.5017 12.4976	
			TIMKEN	93750-93125	12.5000	7.5000	1.8125	2.5000	52	1.000	7.5040 7.5050	12.5010 12.5010	7.5000 7.5010
			ROLLWAY	MF-5232	11.4173 11.4157	6.2992 6.2982	3.8750	3.8750	25	1.125	6.3004 6.2994	11.4229 11.4201	
			S.K.F.	22330	12.5984	5.9055	4.2520	4.2520	28	1.85	5.9066 5.9058	12.6016 12.5984	
			NORMA HOFFMANN	RMS-24½	13.0000	6.5000	2.5000	2.5000	16	1.375	6.5007 6.5012	12.9985 12.9980	
80,000#	40	30"	HYATT	W-228	8.8445 8.8425	5.5122 5.5110	4.7500	4.7500	22	1.0625	5.5138 5.5131	8.8451 8.8419	
			TIMKEN	99600-99100	10.0000	6.0000	1.8750	2.6250	38	1.000	6.0035 6.0040	10.0020 10.0000	6.0000 6.0010
			ROLLWAY	MF-5228	8.8445 8.8413	5.5118 5.5108	3.2500	3.2500	28	.875	5.5130 5.5120	8.8473 8.8442	
			S.K.F.	22324	10.2362	4.7244	3.3860	3.3860	28	1.50	4.7256 4.7244	10.2390 10.2342	
			NORMA HOFFMANN	RMS-23	10.0000	5.0000	2.0000	2.0000	16	1.125	5.0007 5.0012	10.0085 9.9980	
100,000#	30	30"	HYATT	W-234	12.2079 12.2047	6.2934 6.2520	5.3750	5.3750	21	1.375	6.2954 6.2934	12.2098 12.2035	
			TIMKEN	94650-94113	11.3750	6.5000	1.8750	2.5000	46	1.000	6.5030 6.5020	11.3770 11.3750	6.5000 6.5010
			ROLLWAY	MF-5230	10.0394 10.0383	5.5133 5.5045	3.5000	3.5000	26	1.000	5.5057 5.5047	10.0427 10.0379	
			S.K.F.	22328	11.8110	5.5118	4.0160	4.0160	28	1.730	5.5127 5.5118	11.8140 11.8110	
			NORMA HOFFMANN	RMS-24	12.0000	6.0000	2.2500	2.2500	16	1.250	6.0007 6.0012	11.9985 11.9980	
125,000#	30	30"	HYATT	SW-240	13.3852 13.3838	7.8745 7.8730	6.8750	6.8750	24	1.375	7.8775 7.8756	13.3882 13.3826	
			TIMKEN	210750-211300	13.0000	7.5000	DOUBLE	CONE	42	1.250	7.5040 7.5050	13.0080 13.0010	7.5000 7.5010
			ROLLWAY	MF-5232	11.4173 11.4157	6.2992 6.2982	3.8750	3.8750	25	1.125	6.3004 6.2994	11.4229 11.4201	
			S.K.F.	22332	13.3858	6.2992	4.4880	4.4880	28	1.970	6.3006 6.2998	13.3889 13.3858	
			NORMA HOFFMANN	R.M.S-25	13.5000	7.0000	2.5000	2.5000	18	1.375	7.0007 7.0012	13.4985 13.4980	

ILLUSTRATIONS SHOW TYPICAL INDIVIDUAL MOUNTINGS. BUILDERS PRACTICE PROVIDES SAME MFG. BEARING BOTH ENDS OF SHAFT

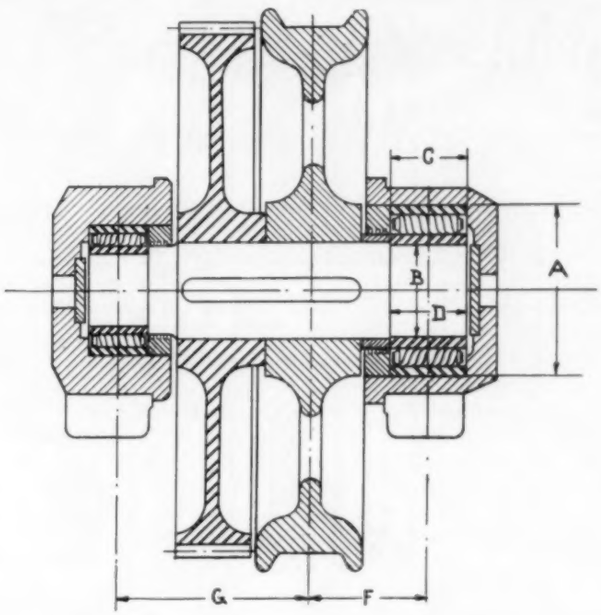
TABLE-D2



CLEVELAND CRANE DATA

MAX. LOAD PER WHEEL	R.P.M.	WHEEL DIA.	BEARING M'F'G.	BEARING SIZE	A	B	C	D	ROLLER Nº	ROLLER DIA.	SHAFT DIA.	HOUSING BORE
25,000#	125	18"	HYATT	W-218	6.3008 6.2992	3.5436 3.5426	2.8125	2.8125	22	.6875	3.5454 3.5442	6.3011 6.2980
			TIMKEN	759-752	6.3750	3.5000 3.5010	1.5000	1.9000	34	.750	3.5010 3.5000	6.3750 6.3770
			ROLLWAY	MF-5216	5.5118	3.1496	1.7500	1.7500	27	.500	3.1504 3.1498	5.5158 5.5138
			S.K.F.	22315	6.2992	2.9528	2.1650	2.1650	28	.828	2.9538 2.9530	6.3018 6.2992
			NORMA-HOFF.	R-375	6.2992	2.9528	1.4570	1.4570	14	.750	2.9538 2.9533	6.2985 6.2990
40,000#	100	18"	HYATT	W-222	7.8758 7.8740	4.3316 4.3299	3.5000	3.5000	21	.875	4.3332 4.3318	7.8763 7.8736
			TIMKEN	938-932	8.3750	4.5000 4.5010	2.1250	2.6250	30	1.00	4.5010 4.5000	8.3770 8.3750
			ROLLWAY	MF-5220	7.0866	3.9370	2.3750	2.3750	23	.750	3.9380 3.9372	7.0906 7.0886
			S.K.F.	22318	7.4803	3.5433	2.5200	2.5200	28	1.062	3.5445 3.5436	7.0831 7.0803
			NORMA-HOFF.	R-390	7.4803	3.5433	1.6930	1.6930	15	.875	3.5443 3.5438	7.4801 7.4786
30,000#	100	24"	HYATT	W-220	7.0883 7.0866	3.9373 3.9363	3.2500	3.2500	22	.750	3.9383 3.9380	7.0887 7.0863
			TIMKEN	861-854	7.5000	4.0000 4.0010	1.7500	2.2650	34	.875	4.0010 4.0000	7.5000 7.5020
			ROLLWAY	MF-5218	6.2992	3.5433	2.0625	2.0625	28	.562	3.5443 3.5435	6.3031 6.3011
			S.K.F.	22317	7.0866	3.3465	2.3620	2.3620	28	.984	3.3477 3.3468	7.0897 7.0866
			NORMA-HOFF.	R-385	7.0866	3.3465	1.6140	1.6140	14	.875	3.3475 3.3470	7.0864 7.0859
45,000#	75	24"	HYATT	W-222	7.8758 7.8740	4.3310 4.3299	3.5000	3.5000	21	.875	4.3332 4.3318	7.8763 7.8736
			TIMKEN	938-932	8.3750	4.5000 4.5010	2.1250	2.6250	30	1.00	4.5010 4.5000	8.3770 8.3750
			ROLLWAY	MF-5220	7.0866	3.9370	2.3750	2.3750	23	.750	3.9380 3.9372	7.0906 7.0886
			S.K.F.	22318	7.4803	3.5433	2.5200	2.5200	28	1.062	3.5445 3.5436	7.0831 7.0803
			NORMA-HOFF.	R-400	8.4646	3.9370	1.8500	1.8500	14	1.00	3.9380 3.9375	8.4644 8.4639
60,000#	50	24"	HYATT	W-226	9.0571 9.0551	5.1185 5.1173	4.2500	4.2500	21	1.00	5.1209 5.1193	9.0576 9.0546
			TIMKEN	95500-95925	9.2500	5.0000	1.9375	2.5000	34	1.00	5.0010 5.0000	9.2520 9.2500
			ROLLWAY	MF-5224	8.4646	4.7244	3.0000	3.0000	28	.750	4.7254 4.7246	8.4694 8.4670
			S.K.F.	22322	9.4488	4.3307	3.1500	3.1500	28	1.375	4.3319 4.3310	9.4516 9.4488
			NORMA-HOFF.	R-405	8.8583	4.1339	1.9290	1.9290	16	1.00	4.1348 4.1344	8.8591 8.8576
75,000#	50	24"	HYATT	W-228	9.8445 9.8425	5.5122 5.5110	4.7500	4.7500	22	1.0625	5.5148 5.5131	9.8451 9.8419
			TIMKEN	95525-95925	9.2500	5.2500	1.9375	2.5000	34	1.00	5.2510 5.2500	9.2520 9.2500
			ROLLWAY	MF-5226	9.0552	5.1181	3.1250	3.1250	26	.875	5.1193 5.1183	9.0600 9.0576
			S.K.F.	22324	10.2362	4.7244	3.3860	3.3860	28	1.50	4.7256 4.7247	10.2390 10.2362
			NORMA-HOFF.	RMS-23	10.0000	5.0000	2.0000	2.0000	16	1.125	5.0010 5.0005	9.9265 9.9250
60,000#	50	27"	HYATT	W-226	9.0571 9.0551	5.1185 5.1173	4.2500	4.2500	21	1.00	5.1209 5.1193	9.0576 9.0546
			TIMKEN	95500-95925	9.2500	5.0000	1.9375	2.5000	34	1.00	5.0010 5.0000	9.2520 9.2500
			ROLLWAY	MF-5224	8.4646	4.7244	3.0000	3.0000	28	.750	4.7254 4.7246	8.4694 8.4670
			S.K.F.	22322	9.4488	4.3307	3.1500	3.1500	28	1.375	4.3319 4.3310	9.4516 9.4488
			NORMA-HOFF.	R-405	8.8583	4.1339	1.9290	1.9290	16	1.00	4.1348 4.1344	8.8581 8.8576
80,000#	50	27"	HYATT	W-228	9.8445 9.8425	5.5122 5.5110	4.7500	4.7500	22	1.0625	5.5148 5.5131	9.8451 9.8419
			TIMKEN	99550-99100	10.0000	5.5000	1.8750	2.2650	38	1.00	5.5010 5.5000	10.0020 10.0000
			ROLLWAY	MF-5226	9.0552	5.1181	3.1250	3.1250	26	.875	5.1193 5.1183	9.0600 9.0576
			S.K.F.	22324	10.2362	4.7244	3.3860	3.3860	28	1.50	4.7256 4.7247	10.2390 10.2362
			NORMA-HOFF.	RMS-23	10.0000	5.0000	2.0000	2.0000	16	1.125	5.0010 5.0005	9.9265 9.9250
100,000#	50	27"	HYATT	W-234	12.2070 12.2047	6.6934 6.6920	5.3750	5.3750	21	1.375	6.6964 6.6944	12.2079 12.2029
			TIMKEN	280625-281200	12.0000	6.2500	DOUBLE	CONE	38	1.25	6.2510 6.2500	12.0030 12.0010
			ROLLWAY	MF-5230	10.6300	5.9055	3.5000	3.5000	26	1.00	5.9067 5.9057	10.6357 10.6329
			S.K.F.	22328	11.8110	5.5118	4.0160	4.0160	28	1.734	5.5132 5.5121	11.8142 11.8110
			NORMA-HOFF.	RMS-24	12.0000	6.0000	2.2500	2.2500	16	1.250	6.0010 6.0005	11.9585 11.9580
80,000#	40	30"	HYATT	W-228	9.8445 9.8425	5.5122 5.5110	4.7500	4.7500	22	1.0625	5.5148 5.5131	9.8451 9.8419
			TIMKEN	99550-99100	10.0000	5.5000	1.8750	2.2650	38	1.00	5.5010 5.5000	10.0020 10.0000
			ROLLWAY	MF-5226	9.0552	5.1181	3.1250	3.1250	26	.875	5.1193 5.1183	9.0600 9.0576
			S.K.F.	22324	10.2362	4.7244	3.3860	3.3860	28	1.50	4.7256 4.7247	10.2390 10.2362
			NORMA-HOFF.	RMS-23	10.0000	5.0000	2.0000	2.0000	16	1.125	5.0010 5.0005	9.9265 9.9250
100,000#	40	30"	HYATT	W-234	12.2070 12.2047	6.6934 6.6920	5.3750	5.3750	21	1.375	6.6964 6.6944	12.2079 12.2029
			TIMKEN	280625-281200	12.0000	6.2500	DOUBLE	CONE	38	1.25	6.2510 6.2500	12.0030 12.0010
			ROLLWAY	MF-5230	10.6300	5.9055	3.5000	3.5000	26	1.00	5.9067 5.9057	10.6357 10.6329
			S.K.F.	22328	11.8110	5.5118	4.0160	4.0160	28	1.734	5.5132 5.5121	11.8142 11.8110
			NORMA-HOFF.	RMS-24	12.0000	6.0000	2.2500	2.2500	16	1.250	6.0010 6.0005	11.9585 11.9580
120,000#	40	30"	HYATT	SW-240	13.3882 13.3858	7.8745 7.8730	6.8750	6.8750	24	1.375	7.8779 7.8750	13.3842 13.3840
			TIMKEN	280700-281200	12.0000	7.0000	DOUBLE	CONE	38	1.25	7.0010 7.0000	13.0030 13.0010
			ROLLWAY	MF-5232	11.4174	6.2992	3.8750	3.8750	25	1.125	6.3004 6.2994	11.4229 11.4201
			S.K.F.	22332	13.3858	6.2992	4.4880	4.4880	28	1.968	6.3006 6.2995	13.3890 13.3858
			NORMA-HOFF.	RMS-25	13.5000	7.0000	2.5000	2.5000	18	1.375	7.0012 7.0007	13.4985 13.4980

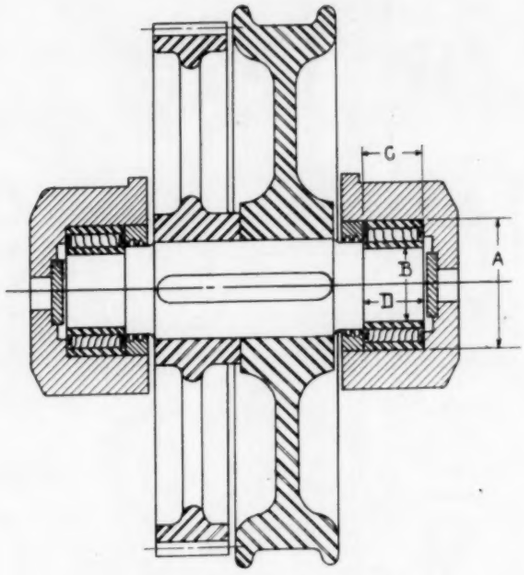
TABLE-D3



P. & H. CRANE DATA

MAX. LOAD PER WHEEL	R.P.M	WHEEL DIA	BEARING M'F'G.	BEARING SIZE	A	B	C	D	ROLLER Nº	ROLLER DIA.	SHAFT DIA.	HOUSING BORE	F	G
20,000#	53 To 213	18"	HYATT	W-215	5.1197 5.1179	2.9542 2.9532	2.6250	2.6250	24	.500	2.9546 2.9541	5.1179 5.1197		8½"
				W-218	6.3011 6.2989	3.5450 3.5438	2.8125	2.8125	22	.6875	3.5454 3.5449	6.2989 6.3011	5 3/32"	
25,000#	46 To 182	21"	HYATT	W-216	5.5135 5.5116	3.1511 3.1500	2.6250	2.6250	23	.5625	3.1515 3.1510	5.5116 5.5135		9"
				W-219	6.6949 6.6926	3.7420 3.7408	3.0000	3.0000	21	.750	3.7424 3.7419	6.6926 6.6949	5 3/16"	
35,000#	40 To 160	24"	HYATT	W-218	6.3011 6.2989	3.5450 3.5438	2.8125	2.8125	22	.6875	3.5454 3.5449	6.2989 6.3011		9"
				W-222	7.8763 7.8736	4.3327 4.3313	3.5000	3.5000	21	.875	4.3332 4.3325	7.8736 7.8763	5 5/16"	
45,000#	40 To 160	24"	HYATT	W-219	6.6949 6.6926	3.7420 3.7408	3.0000	3.0000	21	.750	3.7424 3.7419	6.6926 6.6949		9⅛"
				W-224	8.4670 8.4642	4.7266 4.7251	3.8750	3.8750	21	.9375	4.7271 4.7263	8.4642 8.4670	5½"	
55,000#	40 To 160	24"	HYATT	W-222	7.8763 7.8736	4.3327 4.3313	3.5000	3.5000	21	.875	4.3332 4.3325	7.8736 7.8763		9¾"
				W-226	9.0576 9.0546	5.1205 5.1189	4.2500	4.2500	21	1.00	5.1209 5.1202	9.0546 9.0576	6 1/16"	
65,000#	40 To 160	24"	HYATT	W-224	8.4670 8.4642	4.7266 4.7251	3.8750	3.8750	21	.9375	4.7271 4.7263	8.4642 8.4670		9⅞"
				W-228	9.8451 9.8419	5.5144 5.5127	4.7500	4.7500	22	1.0625	5.5148 5.5140	9.8419 9.8451	6 5/16"	
80,000#	36 To 142	27"	HYATT	W-226	9.0576 9.0546	5.1205 5.1189	4.2500	4.2500	21	1.00	5.1209 5.1202	9.0546 9.0576		11¾"
				W-234	12.2079 12.2039	6.6960 6.6940	5.3750	5.3750	21	1.375	6.6964 6.6954	12.2039 12.2079	6¾"	

TABLE-D4



MANNING, MAXWELL & MOORE CRANE DATA

Max. Load Per Wheel	R.P.M.	Wheel Dia.	Bearing M'f'g.	Bearing Size	A	B	C	D	Roller No	Roller Dia.	Shaft Dia.	Housing Bore
20,000#	80	15"	Hyatt	W216	5.5135 5.5116	3.1515 3.1503	2.6250	2.6250	23	.5625		
25,000#	65	18"	Hyatt	W218	6.3011 6.2989	3.5454 3.5442	2.8125	2.8125	22	.6875		
42,000#	55	21"	Hyatt	W222	7.8763 7.8736	4.3332 4.3318	3.5000	3.5000	21	.875		
42,000#	55	24"	Hyatt	W222	7.8763 7.8736	4.3332 4.3318	3.5000	3.5000	21	.875		
65,000#	70	24"	Hyatt	W228	9.8451 9.8419	5.5148 5.5131	4.7500	4.7500	22	1.0625		

TABLE-D5

Applying the Principles of Steel Mill Practice to Arc Welding

By J. B. AUSTIN*

The fundamental principles applied in the manufacture of electric furnace steels are similarly employed in the latest processes of electric arc welding. The steel maker starts with a known base and adds alloying ingredients or deoxidizers in proper proportions to produce a steel of a given composition. By varying these charges different steels are produced. Likewise, the modern arc welder selects a known base metal or electrode having good arc characteristics and to this base he applies in the form of a coating alloying ingredients or deoxidizers in predetermined quantities. The arc is a miniature furnace in which the alloying ingredients unite with the base metal or electrode. The plate is the mold in which the alloy is directly cast. The weld metal has definite physical characteristics controlled through the coating and the arc welder varies the coating according to the weld metal requirements.

With this elemental steel making process at his command the arc welder is able to match the composition of the material which he welds. While the renewal of wearing surfaces on high manganese steel castings is a highly specialized application of arc welding, it may be cited as a most interesting illustration of this process of alloying steel in the arc. The maximum wearing qualities are obtained when this alloy has a manganese content of 10% to 15% and a carbon content of 0.95% to 1.40%. A relatively slight drop below this range in the manganese content of high manganese steel results in a considerable reduction in the wearing qualities of the metal. In the arc there is a considerable loss of manganese and carbon. Obviously, if the electrode and the plate are of the same composition the deposited metal will most likely be of inferior quality. The skilled steel maker takes these losses into account in charging the furnace. The experienced arc welder accounts for these losses by incorporating sufficient alloy ingredients in the coating. The arc welder is thereby able definitely to control his weld and deposit the best composition of high manganese steel.

Let us first consider the arc welders method of making alloy steels as applied to this high manganese steel alloy. A low carbon steel base rod is given a uniform coating of alloy ingredients carefully controlled as to weight. When an arc is struck the coating dissolves into the globule of molten metal which forms at the tip of the electrode. A series of alloy globules are then projected across the arc to form the bead. If the arc is broken and a magnet is applied to the globule of metal which remains at the electrode tip it will be found to be non-magnetic whereas the unmelted low carbon base rod immediately adjacent to the globule is magnetic. This test clearly shows a positive alloying action occurring in each drop of metal before it leaves the electrode. The test further illustrates how basic raw materials in pre-determined quantities are alloyed in the arc to produce a steel of specific characteristics. This same principle is carried out in depositing many other types of ferrous and non-ferrous alloys. Electrodes which deposit metal of rail steel hardness, or tool steel hardness or metal highly resistant to corrosion or metal of high strength and ductility may have the same base rod of low carbon steel and differ only as to the coating ingredients.

The use of a low carbon base rod and a heavy alloy coating also affords additional advantages in the actual welding process. For example, in welding high manganese steel it is essential to keep the base or parent metal as cool as possible in order properly to quench the deposited metal. This is usually accomplished by frequently quenching the work with water. The heavy refractory coating on this electrode, however, concentrates the heat at the electrode tip so that it is possible to use a lower current than is generally necessary for an alloy electrode of similar diameter. Furthermore, welders generally recognize that an alloy electrode does not display the same degree of arc stability as a low carbon steel electrode. By making use of a low carbon base rod and by introducing the alloying ingredients in the coating a greatly improved alloy depositing electrode is obtained which closely approaches the mild steel rod in arc stability.

A very important function of the coating used on the arc welding electrode is to provide a purifying and deoxidizing action in the arc. Exhaustive investigations of arc fused weld metal have shown that low ductility is due primarily to the unsoundness of its structure and the presence of oxides and other non-metallic inclusions. The skilled arc welder follows the same general principles established in the mill and introduces active deoxidizers into the coating which unite with the molten rod metal in the arc and eliminate impurities from the deposit in the form of a slag. Evidence will be presented to show that the ductility and other physical properties of mild steel deposits have been greatly improved through the use of deoxidizer coatings.

A consideration at this time of a specific structural steel welding problem which in its solution involved a thorough investigation of stresses, a study of the physical characteristics of the weld metal and the importance of proper design will illustrate the underlying principles in structural welding design. This outstanding structural welding problem which has been successfully solved is the seam welded rail joint as applied to modern paved track construction. This development is remarkable first, because it involves the joining of very rigid members of high carbon steel and secondly, because the

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welded structure is subjected to a rare combination of extremely high stresses. This is a most striking example of the arc weld successfully and economically supplanting a purely bolted or riveted structure which in the past proved rarely successful and very costly in maintenance.

The failures encountered with this structure generally result from cupping of the high carbon members. Cups develop as a result of the cold rolling of the metal into the gap if any between adjoining rail ends. As the cup increases in length and depth the impact blows delivered to the structure by passing car wheels increases rapidly in magnitude, leading to early failure of the joint structure and the adjacent paving. Experience bears out the fact that bolted or riveted joints depreciate rapidly and particularly in climates where wide temperature variations are encountered. The renewal of the cupped areas by building up with high carbon steel is a temporary repair at the best and a costly one. To prevent failures due to cupping and impact the gap between the rail ends must be eliminated entirely by bringing the squared rail ends under mutual compression and by welding the structure in such a manner as to maintain this condition permanently.

Mutual compression is obtained mechanically. The outer holes in the joint members are drilled slightly eccentric. Hardened tapered drift pins are driven in to force the high carbon members together. The ends are milled square and undercut so as to assure good bearing contact throughout the head area. The middle bolts are drawn tightly and maintain the compression while the drift pins are replaced with bolts. Low carbon plates designed for welding are seam welded to the high carbon members along the upper and lower bearing areas. The actual welding operation fortunately increases the degree of compression. The welding heat expands the plates during the welding operation and the contraction on cooling draws the rails together. The order of welding has been definitely established in regards to keeping the joint straight.

The principle which is followed in the design of this structure is first, to provide the best possible mechanical joint so that any blow applied to the ball of the rail is largely absorbed by the joint structure and not transmitted directly to the seam welds. However, there are some variations in rolling and the seam weld is accordingly designed to compensate for any lack of mechanical quality in the joint structure.

The weld metal which unites the members of this structure must have very definite characteristics. It must be primarily ductile to resist contraction stresses and it must be highly resistant to repeated impact stresses to withstand the constant pounding which the joint receives. The seams must also be strong enough to withstand the maximum tensile stresses due to temperature changes. A joint with 24″ plates is designed to develop a total tensile strength in the seam welds of about 450,000 pounds. High welding currents resulting in deep penetration into the rail must be avoided to assure against carbon absorption by the seam. Such welds are brittle and may develop initial shrinkage cracks or early fatigue failure. A relatively low welding current with a pronounced puddling action is essential in producing ductile welds in high carbon members. A large volume of ductile weld metal is introduced into the crater from the electrode which dilutes the carbon absorbed from the high carbon member. The electrode is coated with metallic deoxidizers which exert a strong cleansing and purifying action analogous to the deoxidization of steel in the foundry.

The following bend and repeated impact tests clearly show the improvements effected in the quality of the arc fused steel through the addition of deoxidizers: Bend test specimens were prepared by machining ¼″ x ⅞″ x 6″ bars from actual weld metal. These bars were bent around a 1″ diameter pin, with the ⅞″ side perpendicular to the axis of the pin. Five specimens made with the bare rod averaged 42° bend to failure, and thirteen specimens made with the same rod coated with deoxidizers averaged

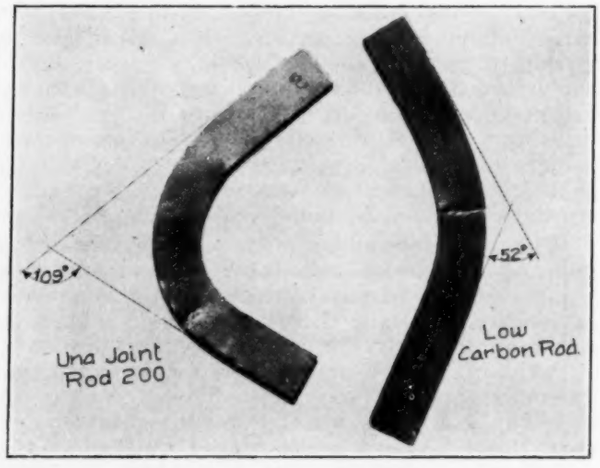

FIG. 1—Bend Test Specimens Showing Improvement in Ductility Obtained With a Properly Coated Electrode.

86°. The bars made with bare rods gave rectangular fractures, whereas the thickness of the bars made with the coated rods was considerably increased on the inside and decreased on the outside edge, showing evidence of considerable ductility. Repeated impact tests were made as follows: Rail joints consisting of two 16″ sections of 6″, 100 lb. T rail and two 1″ x 24″ flat bar plates were bolted up with a 1/16″ gap between rail ends. The top seams were then welded on each side. The base seams were omitted so that the impact blow would be absorbed largely by the weld metal rather than by the plates. The welded structure with bolts removed was then tested in a specially devised repeated impact testing machine. The structure rested on a ½″ leather pad supported by a solid steel anvil and 122 ft. lb. blows were delivered to the head at the center of the joint, at the rate of 70 blows per minute. Comparative tests were made of similar joints welded with bare, low carbon filler rod and with the same rod coated with deoxidizers. In each seam, the weight of deposited metal used was approximately the same. Four joints were welded with each type of rod and tested. The seams welded with the bare rod started to fail at 3,100 blows (average) and total failure averaged 19,400 blows. The results with the coated rods were 14,200 and 34,700 blows respectively. These results indicate the great improvements in ductility

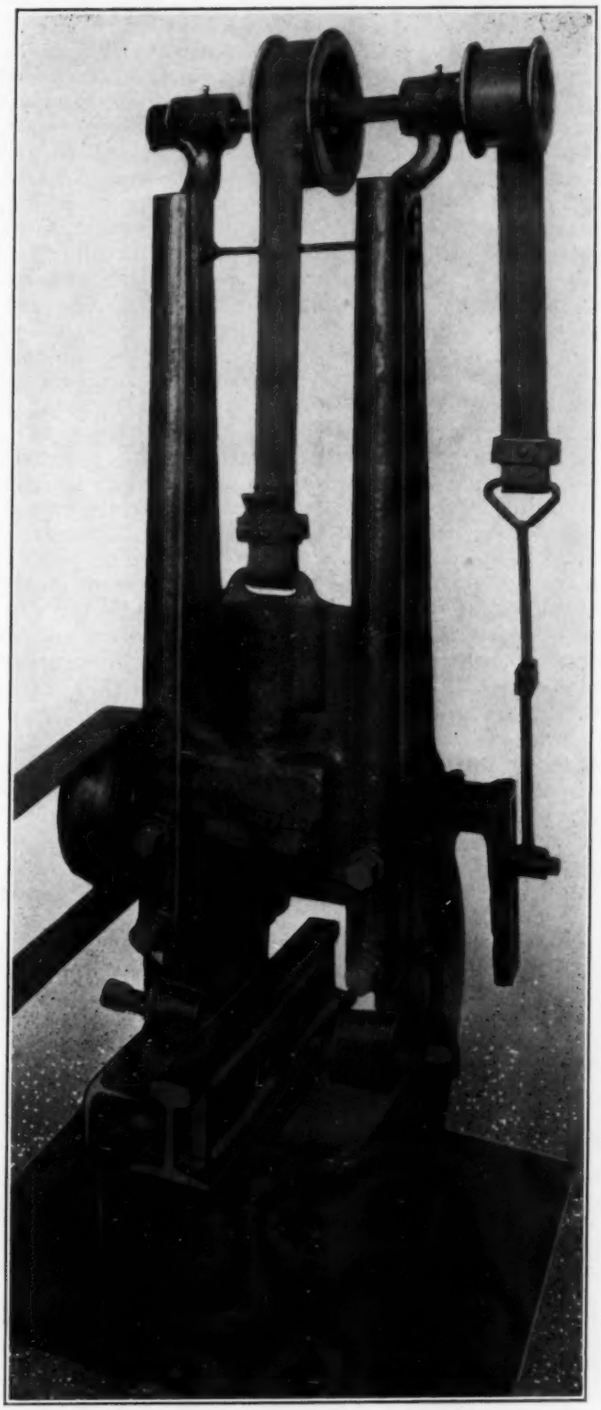

FIG. 2—Repeated Impact Testing Machine.

and resistance to repeated impact stresses of arc fused steel obtained with a deoxidizer coating.

Having refined the metal in the arc to produce a deposit of superior quality, additional improvements in the physical properties of the weld arc are accomplished by the heat treatment (unafying). The seam first deposited is quite coarse grained, due to the high temperature which is reached in welding. A heat treating blanket of weld metal is deposited upon the coarse structure of the first seam, which together with the portions of the rail and plate are thereby heated slightly above the critical temperature, thereby refining the grain structure. This refinement is quite pronounced in high carbon welds and extends through the junction area of the weld into the high carbon member, where the improvement is most effective.

FIG. 3—Microstructure of junction area of single seam weld (light area) and high carbon rail (dark area.)

FIG. 4—Microstructure of the same junction after heat treating or unafying blanket has been applied.

The welding process introduces stresses in the structure which must be given careful consideration. A thorough analysis was made of these stresses by means of a Berry Strain Gage. Further conclusive information was obtained by conducting repeated impact tests of the welded structure and by bending 6 ft. standard welded sections to failure. The application of the arc heat to high carbon steel may create a local hardening or notch effect. Since the structure is supported on ties and when under wheel load is subjected to a considerable flexural stress, the seams as well as plates should not end in the

same vertical plane but should be staggered. Where the welded structure is under load and subjected to flexural stress the lower part of the plate is under high tensile stress. It was discovered that by omitting the welding from the central part of base seams that the fatigue life of the plate was materially increased. In other words, the welding stresses were eliminated from the plate at the point where it was subjected to the maximum tensile stress and where fatigue failures generally originated in the test. Welding stresses in rigid structural fabrication may prove disastrous unless they are analyzed and proper provision is made in the design of the structure and in the welding procedure.

Some years ago, before very much thought had been given to this structural welding problem, 100% impact-fatigue failures of the seam welds were encountered in testing standard welded joints in the repeated impact testing machine, previously referred to, at less than 100,000-122 ft.-lb. blows. The 122 ft.-lb. blow was selected because it represented a very severe condition as compared with the blow which is normally encountered in actual service. It might be further added that the failures obtained in the testing machine at that time were of a similar nature to those observed in actual service. Through improvements in structural design and in the arc welding process, the modern joint withstands up to 600,000 or more of these blows without a sign of seam failure. A slowly developed fatigue fracture of the plate, consistently results in this test, showing that the plate is now the weakest member rather than the seam weld. While plate failures have been consistently obtained in this test due to the extreme severity of the blow, such failures in actual track installations have been practically unknown. There are many thousands of these joints welded under similar specifications which have been in service and under observation in various cities during the past six years, and to date show practically no signs of cupping or failure.

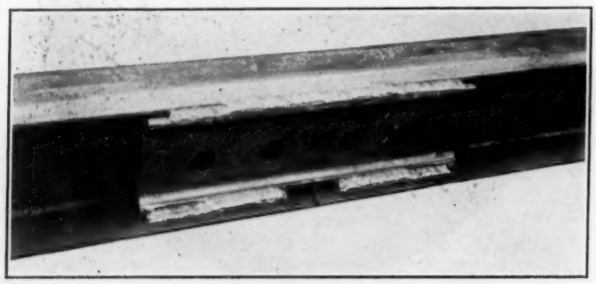

FIG. 5—Seam Welded Rail Joint Structure Showing Structural Design and Seam Location.

About two years ago, a prominent mid-western interurban line installed two miles of paved track construction. 130 lb. A. S. C. E. rails were used and these joints were all seam welded. The interesting feature of this installation is the fact that regular freight service is maintained over the track and the trains of 40 or more loaded cars are drawn by two 80 ton electric locomotives. The joints have been frequently inspected and to date no sign of failure has been observed. Considering the nature of the service, this track installation is unique and represents a distinct step forward, in welded structural design.

The coating applied to the welding rod may be designed to exert a distinct fluxing action along the surfaces of the metals joined. The blacksmith makes use of this fluxing action in producing a forge weld. After two bars of steel have been heated to the plastic stage, sand is sprinkled over the surfaces that are to be forge welded. The sand acting as a flux, eliminates the oxide film on the surface, so that the clean metals are united without slag contamination. The process of arc welding copper to steel affords an excellent illustration of this same fluxing principle. The welding of copper bonds to high carbon steel rails is perhaps the largest application of copper to steel welding. In this process, a copper U-shaped bond is directly arc welded to the ball of the rail. The bond terminal is held in proper position by means of a carbon mold which also serves as a crucible for the melting and casting of the electrode metal. The bond terminal extends up ¼" or more through the bottom of the crucible and the rail head forms one side of the mold. The process consists of depositing copper into the bottom of the small crucible and first obtaining fusion to the copper bond terminal. The the pool of molten copper is continuously joined to the rail head as the crucible is filled by further addition.

In carrying out this process with a pure copper electrode, it will be observed that the copper does not make intimate contact with the steel and shows very little tendency to unite with it. Such a weld shears at about 14,000 pounds per square inch and the sheared surface is very porous. The same experiment may be repeated and the arc may be deliberately directed into the rail. In this case, better fusion of the metals is obtained, but an examination of the junction under the microscope, shows a very brittle copper steel alloy zone between the two metals, containing numerous hair-line cracks. This weld is also quite porous. Now if the experiment is repeated, using a pure copper electrode, coated with a metallic deoxidizer in pre-determined quantity, the molten copper quickly flows into intimate contact with the steel. In this case, the arc need not be directed at the rail in order to obtain a weld. The weld metal shears at 28,000 pounds per square inch and is very dense and non-porous, in fact, typical of high grade foundry cast copper. Under the microscope, a straight line junction between the copper and steel is observed with very little evidence, if any, of a brittle alloy zone between the two metals, and no evidence of hair-line cracks. The action of the deoxidizer in this case is to dissolve the rust and scale on the surface of the steel and to degasify the copper adjacent to the steel. The slag which is formed is light and quickly floats to the top of the pool while the clean metals make intimate contact and rapidly unite with the minimum amount of interpenetration of the two metals.

The strength and ductility of arc fused steel deposits have been appreciably increased by the addition of alloying and deoxidizing ingredients to the electrode coating. Tensile tests were made using ½" ship plate which had an ultimate tensile strength of 61,500 pounds per square inch. These tensile specimens were designed to produce failure in the weld

and the welds were sufficiently wide so that 1" punch marks could be located within the welded portion. Comparative tests were made of bars low carbon electrodes and of the same electrodes coated with alloying and deoxidizing elements. The bare mild steel electrode developed an ultimate weld strength

FIG. 6—Microstructure of copper-to-steel weld junction obtained with a deoxidizer coated electrode.

of 48,000 to 54,000 pounds per square inch and an elongation of 3.5% to 5% in 1". The coated rod developed an unltimate weld strength of 60,000 to 65,000 pounds per square inch and an elongation of 15% to 18% in 1".

A weld of high strength and high ductility is required for the fabrication of many rigid structures. An analysis of the plate butt welding problem reveals the importance of these characteristics. The majority of structural shapes used in welded fabrication have an ultimate strength of 55,000 to 65,000 lbs. per square inch and the yield point is approximately one half of the ultimate strength. Weld metal deposited with a mild steel electrode develops an ultimate strength of 45,000 to 55,000 lbs. per square inch. While the ultimate tensile strength of the mild steel weld does not equal the maximum tensile limit of the plate, the elastic limit of the weld is considerably greater than that of the plate. In other words, the weld is considerably stiffer than the plate. A cubic inch of arc deposited metal contracts approximately .0117 inch per inch as it cools down from the freezing temperature. The contraction of the weld metal necessarily means that the weld must either absorb the stresses resulting from contraction or that the plate must distort and relieve the stress. The welding of light plates does not present any particular problem because the volume of weld metal is low and the plate bends or distorts more easily than the mild steel weld and stresses are relieved. On the other hand, when heavy plates are arc welded the greater volume of weld metal results in greater contraction stresses and the plate resists distortion to a much greater degree because of its higher moment of inertia. Consequently, the welded seam in rigid structures must absorb the contraction stresses and should be ductile. If the structure is such that high stresses result in the seam weld it is essential that the welded joint should have an ultimate strength at least equal to the maximum limit of the plate specification. The use of very heavy re-inforcing is not the best means of developing this extra joint strength because the heavy re-enforcement concentrates stresses at the edge of the weld where there is a change in section. The proper procedure is to introduce weld metal of sufficient strength so that excessive re-enforcing is not required to develop the maximum plate strength.

Residual stresses can be completely relieved by annealing. However, this procedure is frequently impractical so that other methods must be resorted to in order to minimize these stresses. Cold peening of the weld metal mechanically relieves contraction stresses to a limited extent. These stresses may be further minimized by following a definite order of welding. If the operator starts in at one end of a long seam and welds continuously towards the other end, the maximum temperature is reached and the residual stresses are high. Contraction or residual stresses may be minimized in welding long seams by using the step-back method of welding. By this process, the operator starts at a point, for example, 10 inches from the end and works toward the end of the seam, then he jumps to a point 10 inches from the end of that seam and works back until he meets the first weld, and so on.

The arc welding of the 18% chrome, 8 nickel stainless steel alloy has been successfully accomplished through the use of deoxidizers in the coating. A weld made with a bare alloy electrode of the same composition is extremely porous and there are numerous slag pockets left on the surface of the bead and extending well into the deposit. By coating the same alloy electrode with deoxidizers a very dense deposit is obtained which is entirely free from slag and perfectly homogeneous.

The corrosion resistance of arc fused steel has been considerably increased by introducing certain alloys in definite proportions in the coating of a low carbon steel electrode. A hot rolled steel plate 1" x 1" x ⅛" was suspended in a 10% solution of Hydrochloric acid for 12 days and there was a 7.3% loss in weight. A similar test made with a plate machined entirely from arc deposited metal, using a bare low carbon rod, showed a loss of 37.6%. A third plate was machined from weld metal made with the same low carbon electrode, coated with alloying elements and showed a loss of 8.7% in 12 days. This improvement in corrosion resistance is remarkable, when it is considered that the weld as a casting compared favorably with the hot rolled steel plate.

The most essential characteristic required in arc welding electrodes is arc stability: If the operator has an easy flowing electrode and a steady arc at his command, he is free to concentrate his attention in properly locating the weld and in maintaining the proper arc length. With an unstable arc the operator is handicapped in the same sense as the mechanic attempting to work with a dull tool. Arc stability has considerable influence on the density of the weld. If the arc is erratic, the arc length is increased and the metal is overheated and badly oxidized. Elec-

trodes with very stable arc characteristics have been found essential for welding low pressure or storage tanks where extreme density of the deposit is necessary.

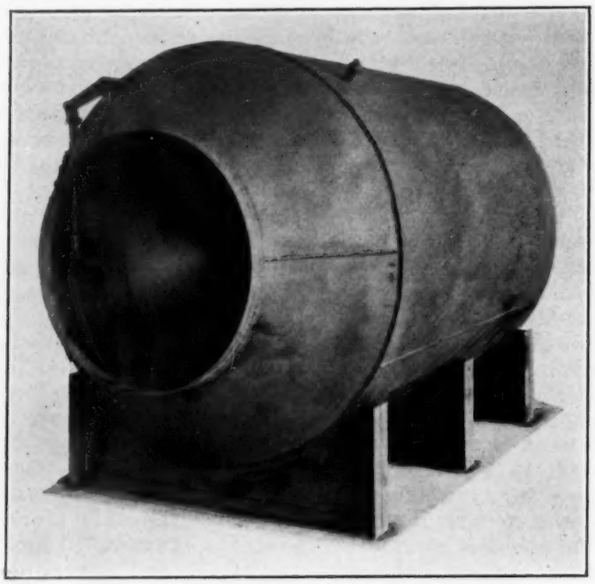

FIG. 7—Direct Fired Heating Furnace Completely Fabricated By Arc Welding.

An investigation of numerous elements applied separately and in combination as rod coatings has shown that certain elements actually lower the melting rate of the bare electrode, whereas other elements tend to increase the melting rate. Automatic welding tests have shown that a coating of a certain type, applied to the surface of a low carbon steel rod, will approximately double the rate of deposition of that rod, at a given arc voltage and amperage. The coating on this electrode stabilizes the arc at high amperages to a remarkable degree. In fact, the arc is stable and free of twirling when drawn but to a length of 1". A very active metallic deoxidizer is introduced to protect the metal from oxidization, when high currents are used. The effect of the coating in increasing the melting rate of the electrode is illustrated by a comparative automatic welding test made under production conditions. The job consisted of butt welding a tube of 2" No. 14 gauge .10 carbon steel. Comparative runs were made with 5/32" bare rod and 5/32" coated high speed wire of the same base composition. The results were as follows:

Bare Wire	20 volts, 280 amperes
Coated Wire	23 volts, 240 amperes

Actual arc drawing time:

Bare Wire	22 seconds
Coated Wire	9 seconds
Bare Wire Melted	5.5 inches
Coated Wire Melted	5.75 inches

This test shows that with less current, ¼" more of the coated wire was melted in less than half the time.

While greater arc stability and greater ease and speed of welding have been provided for the operator in the coated electrode, there remains the problem of personal skill on the part of the operator to obtain the ultimate result. The electrode and the metals welded may be controlled to a fine degree, but the joining of those metals is entirely up to the operator. Periodic tests show that a first class manual operator will produce uniform results over a period of time. The chief difficulty lies in the time required to train manual operators to the point where they are proficient. The fundamental difficulty in mastering the arc welding process is the fact that the operator must master two simultaneous motions of the electrode. He grips the electrode at a point about 7" from the arc and maintains, for example, an arc length of ⅛", plus or minus 1/32", while at the same time he advances the electrode in a plane perpendicular to this vertical feeding movement. An arc welding tool recently perfected is instrumental in removing a large part of the personal skill required in arc welding. The welding wire is fed automatically from coils, through an automatic welding head and then through a flexible cable, to the work. The operator holds a trigger switch for starting and stopping the wire feed. The proper arc length is automatically controlled by the head, the operator merely guides the arc, and as a result has only one movement to master. After a relatively short training period, the inexperienced operator is able to produce the best quality welds at rates considerably in excess of manual operation. No electrode change time, no wire waste, increased penetration and the proper use and control of high speed wire at high current densities are the essential features of this welding tool.

In the preceding references to arc welding applications the analogy was drawn between the mill practice of making steel and the arc welders method of alloying and purifying metals in the arc. Illustrations were offered of various coatings applied to mild steel electrodes to provide certain definite characteristics to the deposited metal such as greater hardness, strength, ductility, resistance to corrosion and resistance to repeated impact stresses. Each of these electrodes may be considered as a tool with which the arc welder obtains a certain result. However, the degree of success in any welded fabrication depends largely on the proper analysis of the welding problem and then the proper selection and application of the tool. Many welding applications present simple problems and it is merely a matter of speed, hardness, machineability or some other factor, In other cases, as in the structural problem previously described in detail, the problem is more complicated and such factors as stress and design must be considered in relation to the arc welding process. A thorough analysis of the welding problem in all its related parts is certain to produce successful structures and advance the art of welding.

Theory of Rolling of Plastic Materials

By F. G. Gasche, M.E.*

Early in 1906 it was necessary to make a study of rolling operations with the specification and design of motor drives for mills as an objective. The mills were examined with a precision and experimental detail not previously required in view of the importance of certain basic data and the total absence of any precedent in the way of alternating current motors as applied to rolling mill drives. It was soon evident that the erratic performance of direct connected steam engines caused such difficulty in the use of experimental apparatus that the chief responsibility consisted of correct interpretation of test data. The larger mills operated through the indulgence of speed variations that would now be considered preposterous and because of the presence of fly wheels that were designed for safety instead of a concession to the energy storage requirements.

F. G. GASCHE

After the expenditure of much time, effort and money the mass of seemingly inconsistent test results enforced the conclusion that but little useful information was available for the purposes intended. The problems required answers in different form and principally for the reason that we were endeavoring to define local mill reactions by measuring overall mill loads. Of the several energy demands of a rolling operation there is seldom a necessary relation of one part to another and they certainly could not be totalized by such hypnotic inventions as, "horse power per inch of elongation" and other startling units of measurement of that day.

It occured to the author that a rolling operation is the aggregate of several mechanical actions between moving surfaces combined with internal or body resistances to change of shape of the plastic material. The former may be capable of analysis and numerical estimate through the application of ordinary dynamical principles. Except for the statement of energy demands, the latter is almost beyond the limits of mathematical physics in view of the fact that two more variables, namely: time, and some factor representing molecular friction, will enter all equations which now specify the interior behavior of perfectly elastic materials when stressed. This part of the resistances accompanying a rolling operation is frequently a large part of the total load on a mill and we are fortunate in having a reasonable estimate of the energy demands though we get into formidable difficulties if we attempt to calculate the free surface contour of rolled bars. As in many other matters involving engineering mechanics, but little progress can be made along analytical lines without a limitation of the premises, often to the extent that the results would seem to be only first approximations.

The first limitation consists of the abandonment of any idea of a modulus of elasticity, or a resilience and elastic recoil as applied to a plastic material. Such materials yield to stress and retain their new form at the instant of a partial release of stress until greater stresses are applied. The resistance to change of shape is somewhat of the character of an internal friction of one particle on another and thus throughout the portion of body which suffers deformation. Measured as a stress per unit of area it seems to be sensibly the same whether the external applied forces act in tension, in compression or shear. It is assumed that they are identical in this respect until the contrary is proven experimentally and they will be called simply "fibre strength."

Above 900 degrees Fahr. there is a rapid decrease of tensile strength with increase of temperature. Experimental results are somewhat inconsistent and their adjustment in certain cases has been attempted through the application of the method of "least squares" as summarized in Appendix (A). In any rolling operation the "fibre strength" is sensibly constant during that event.

Rolling Operations:

It is generally possible to locate a point on the roll surface which has the same linear velocity as the delivery or finished part of the rolled bar. The distance from the axis of the roll to this point will be called the "radius of action." All other parts of the active roll surface will have a relative motion with reference to points on the bar with which they are momentarily on contact. In the presence of large forces acting over these contact surfaces the energy losses due to the aggregate of surface abrasions are important. The difficulty in their numerical estimate lies in the uncertainty concerning the coefficient of friction for such surfaces, materials and kind of interaction.

The frictional resistance of roll bearings is materially effected by the difficulties of satisfactory lubri-

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cation though the direction and magnitude of bearing pressures may now be estimated with some approach to the facts as an incentive to the construction of superior types of bearings.

The rolling of hot steel and other plastic material imposes energy demands that are thus enumerated:

1. Internal plastic resistance to change of shape.
2. Surface abrasions between rolls and material.
3. Roll neck friction.
4. Guide friction with bar distortion.
5. External resistances imposed by the driving mechanism.

Notation

S_1 = Horizontal velocity of entry side of bar in feet per sec.
S_2 = Horizontal velocity of delivery side of bar in feet per sec.
S = Horizontal velocity of intermediate point of bar in feet per sec.
L_1 = Original length of bar in feet.
L_2 = Final length of bar in feet.
L = Intermediate length of bar in feet.
A_1 = Original area of bar section, square inches.
A_2 = Final area of bar section, square inches.
A = Intermediate area of bar section, square inches.
R_1 = Radius to the top of a roll groove, inches.
R_2 = Radius to the bottom of a roll groove, inches.
R = Radius to intermediate points of a roll groove, inches.
R_0 = "Radius of Action" applying to the groove, inches.
r = Radius of roll necks, inches.
W = Energy required, (with subscripts as defined) foot pounds.
w = Width of flat (or cylindric) surface at bottom of groove, inches.
V = Volume of bar, cubic inches.
f = Coefficient of friction of plastic material on roll surfaces.
f^1 = Coefficient of friction at roll neck surfaces.
$K = \frac{C}{R_1}$ = Fixed constant for the roll pass.
C = Minor axis of ellipse of contact.
t = Time to complete the pass, seconds.
n = Revolutions of rolls per second.
e = Abstract ratio.
T_0 = Equivalent tangential force at radius R_0.
T_1, T_n = Elementary forces at roll bearings.
S_c = Fibre strength lbs. per square inch.

Work Due to Elongation or Compression of a Block of Plastic Material

Assuming the block to be confined between the parallel plates or dies of a press which offers no constraint to the lateral or radial flow of the plastic material and that there is no volumetric compressibility we have (See fig. 8).

$$A_1L_1 = A_2L_2 = AL = \frac{V}{12} \qquad \text{.....(a)}$$

The force operating on the block at the instant the section is A will be:

$$F = AS_c = A_1S_c\frac{L_1}{L} \qquad \text{.....(1)}$$

For the decrement of length dL, during which F may be assumed to be constant, and with the initial and final lengths of the block L_1 and L_2 the total energy demand in foot pounds is (neglecting die friction):

$$W_t = -\int_{L_1}^{L_2} F\,dL = A_1L_1\int_{L_1}^{L_2}\frac{dL}{L}$$

$$= A_1L_1S_c \log_e\left(\frac{A_1}{A_2}\right)$$

$$= 2.3026\, A_1L_1S_c \log_{10}\left(\frac{A_1}{A_2}\right)$$

$$= 0.1919\, VS_c \log_{10}\left(\frac{A_1}{A_2}\right) \qquad \text{.....(2)}$$

If the change of shape is caused by the action of other parts of the bar upon the selected portion called the "block" there would be no interaction of the nature of die frictions of one part on another to prevent lateral expansion (or contraction) of the "block." In like manner it can be shown that tensile stress applied to the "block" at the ends occupied by the die surfaces of Fig. (8) could account for the same energy demand in realizing the change of shape from the final dimensions of Fig. (8) to their original values. It is not difficult to conceive of the bars delivered by a set of rolls to be made up of an infinite number of small blocks each requiring the energy for the mere change of shape as shown by equation (2) such that the initial and final dimensions are sufficient for the calculation of the aggregate energy demand for this part of the roll action. When a bar is delivered by a pair of rolls having cylindric surfaces this demand is designated by W_t and is often a large part of the total resistance offered by the rolls.

When a bar enters a groove in one or both rolls there still continues the internal plastic resistance, W_t, with displacements of the material chiefly in two directions in view of the lateral constraint of the groove, but now accompanied by violent abrasive actions on the sides of the groove if there is marked difference in the radii of the surfaces. To a definite extent this abrasion, of roll surface on the bar, occurs even with cylindrical rolls when there is a measurable "draft" or reduction of thickness of the bar during a roll "pass."

The precision of the formula for the numerical estimate of these roll actions will depend on the accuracy with which the relative motions of the roll surfaces and the bar are established.

Energy Demands of Roll Collar Action

All operative roll surfaces in "grooves" or "passes" which are not parallel to the roll axis will be called "collars" and their effects on the rolled material is named "collar action." Collar surfaces may be either "radial" or conical with the exception of the relatively small areas occupied by fillets or similar distortions from the straight line boundaries of a rolled bar section. A "radial" collar lies in a plane perpendicular to the roll axis and is bounded by the straight lines and arcs of circles as shown in Fig. (1) by the area A J B M A. Each point in this roll surface will have a path of contact on the rolled bar which is a distorted cycloid. The amount of this distortion is somewhat dependent on the

amount of draft to which the bar is subject and the actual radial distance of a given point on the roll collar from the roll axis. Such a surface would apply to roll groove making a rectangular section having a width equal or less than the original width of the bar.

When the collar surface is "conical" (See Figs. (1), (2) there is produced in the simplest case the well known "diamond" pass in which two similar "conical" collars intersect at the middle of the groove D, or F. In the "diamond" groove D E F G when preceeded by another "diamond" section I E H G

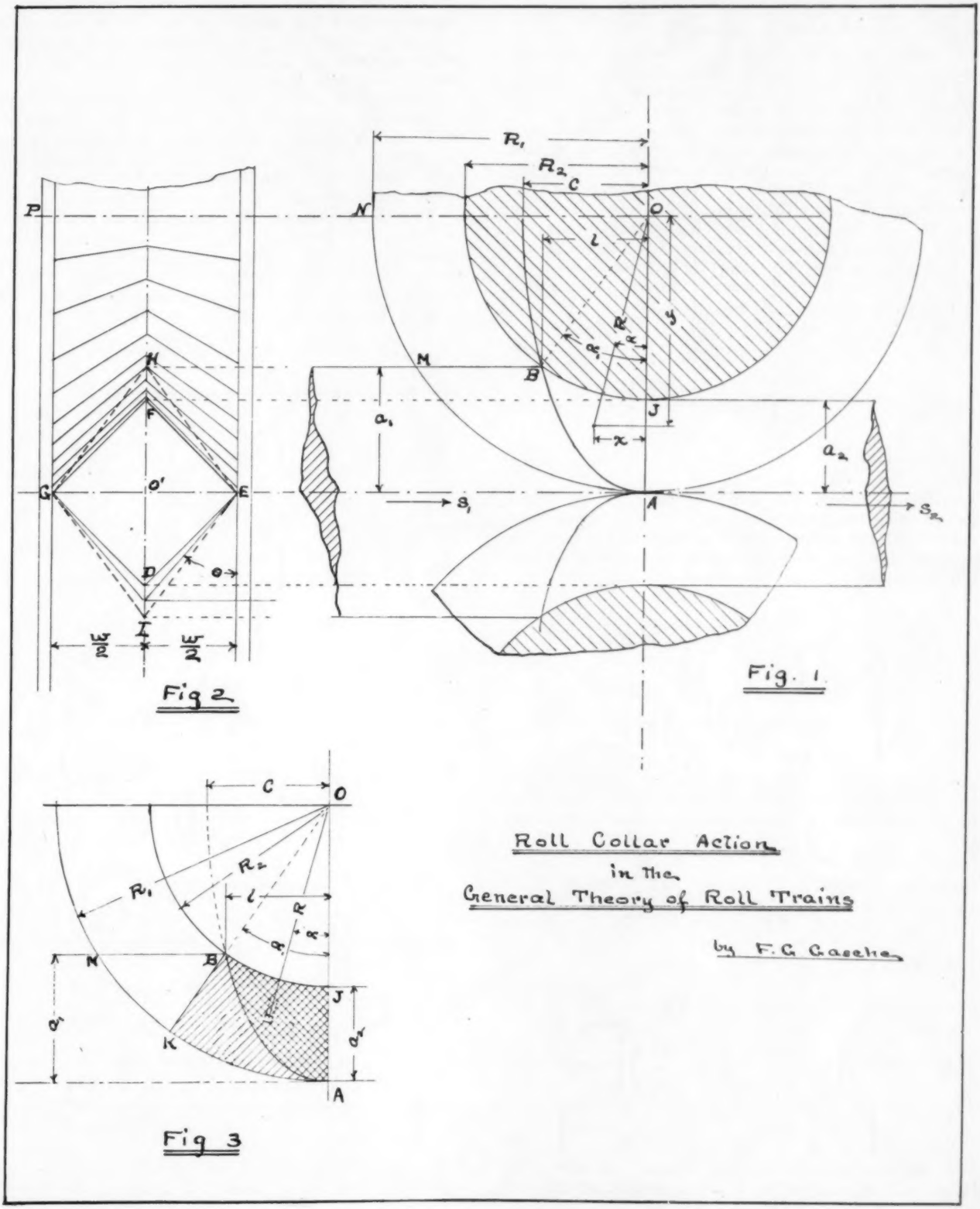


Fig 2

Fig. 1

Fig 3

Roll Collar Action in the General Theory of Roll Trains

by F. G. Gaseha

of the bar there is a limitation of the collar area by the arc A B of an ellipse having O as its center with AO for the semi-major axis $= R_2 + a_2$ and a semi-minor axis C which has a value determined by the fact that B is common to the ellipse and the circle of radius R_2.

$$C^2 = \frac{R_1^2[2R_2(a_1-a_2)-(a_1-a_2)^2]}{R_1^2-[R_2-(a_1-a_2)]^2} \quad \text{.....(3)}$$

The "radius of action" R_0 is not capable of numerical estimate except by the close observation of bars after they have been reshaped by a single pass. Even in this case there is much uncertainty arising from the amount of displacement caused by a particular part of a roll groove together with the condition of the roll surfaces at the time the pass is made. R_0 is seldom as large as R_1 except in the limiting case of plane cylindric plate or sheet rolls. In all other cases R_0 lies between R_2 and R_1 with approximate values estimated through the use of the ratio factor e. For some passes finishing "angle" sections e=3. Channel sections have shown e=6 to e=7. Generally, the following relations obtain, viz:

$$R_0 = R_2 + \frac{R_1-R_2}{e} \quad \text{.....(4)}$$

$$S_2 = 2\pi n R_0 = 2\pi n\left[R_2 + \frac{R_1-R_2}{e}\right] \quad \text{.....(5)}$$

$$\text{Also } \frac{S_1}{S_2} = \frac{A_2}{A_1} \quad \text{.....(6)}$$

Referring to Figs. (1) and (3) and the relations thereon with the understanding that any elementary area within the collar surface is located by a radius vector R standing at an angle α with the vertical line O A we have:

$$S = S_1 + \frac{L-x}{L}(S_1-S_2)$$

$$= S_2\left[1-\frac{x}{L}\left(1-\frac{A_2}{A_1}\right)\right]$$

$$= S_2\left[1-\frac{R\sin\alpha}{R_2\sin\alpha_1}\left(1-\frac{A_2}{A_1}\right)\right] \quad \text{.....(7)}$$

Any part of the roll collar having the same coordinates (R,α) will have a displacement $2\pi ntR$ in the circular path of which the horizontal component is:

$$v = 2\pi ntR\cos\alpha \quad \text{.....(8)}$$

From the foregoing definitions and notations it is apparent that:

$$ts_2 = 2\pi nt R_0 = L_2 \quad \text{.....(9)}$$

$$\text{from which, } 2\pi nt = \frac{L_2}{R_0} \quad \text{.....(10)}$$

The relative displacement of roll collar and bar surface at the point (R,α) in a horizontal direction is:

$$ts - v = ts_2\left[1-\frac{R\sin\alpha}{R_2\sin\alpha_1}\left(1-\frac{A_2}{A_1}\right)\right] - 2\pi ntR\cos\alpha \quad \text{.....(11)}$$

$$= L_2\left[1-\left(1-\frac{A_2}{A_1}\right)\frac{R\sin\alpha}{R_2\sin\alpha_1} - \frac{R}{R_0}\cos\alpha\right] \quad \text{.....(12)}$$

Any surface element $RdRd\alpha$ located at the point (R,α) will be subject to a pressure per square inch S_c and a coefficient of friction f, such that the energy expended in moving the small area over the distance represented by equation (12) is:

$$dw = L_2S_cf\left[1-\left(1-\frac{A_2}{A_1}\right)\frac{R\sin\alpha}{R_2\sin\alpha_1} - \frac{R}{R_0}\cos\alpha\right]RdRd\alpha \quad \text{.....(13)}$$

This applies to each surface element of the bar arranged along a line parallel to the center line of the bar and so situated that it conforms to a specific radial position on the roll collar at the instant of first contact with the roll surface.

As there is such a point for each surface element confined by collars over the entire bar surface the total surface abrasion going on at any instant within the area A J B of Fig. (3) is repeatedly applied for each elementary advance of the bar through the "pass" and ultimately over its entire length.

The energy demand shown by equation (13) must be integrated between the limits o, and α_1, and the limits R_2, and $\varphi(R)$, where $\varphi(R)$ is the function of R represented by the equation of the ellipse A B whose semi-major axis is R_1, and semi-minor axis is c. The latter being derived as shown in (3).

$$\varphi(R) = R^2 = \frac{R_1^2C^2}{C^2\cos^2\alpha + R_1^2\sin^2\alpha} \quad \text{.....(14)}$$

The total abrasion on one roll collar is:

$$W_c = L_2S_cf\int_{R_2}^{\varphi(R)}\int_0^{\alpha_1}\left[1-\left(1-\frac{A_2}{A_1}\right)\frac{R\sin\alpha}{R_2\sin\alpha_1} - \frac{R}{R_0}\cos\alpha\right]RdRd\alpha \quad \text{.....(15)}$$

$$= L_2S_cf\int_0^{\alpha_1}\left[\frac{R^2}{2} - \frac{A_1-A_2}{3A_1R_2\sin\alpha_1}R^3\sin\alpha - \frac{R^3}{3R_0}\cos\alpha\right]_{R_2}^{\varphi(R)}d\alpha \quad \text{.....(16)}$$

$$= L_2S_cf\left\{\int_0^{\alpha_1}\left[\frac{R_1^2C^2}{C^2\cos^2\alpha + R_1^2\sin^2\alpha} - R_2\right]d\alpha - \frac{A_1-A_2}{3A_1R_2\sin\alpha_1}\int_0^{\alpha}\left[\left(\frac{R_1^2C^2}{C^2\cos^2\alpha + R_1^2\sin^2\alpha}\right)^{3/2}\sin\alpha - R^3{}_2\sin\alpha\right]d\alpha - \frac{1}{3R_0}\int_0^{\alpha_1}\left[\left(\frac{R_1^2C^2}{C^2\cos^2\alpha + R_1^2\sin^2\alpha}\right)\cos\alpha - R^3{}_2\cos\alpha\right]d\alpha\right\} \quad \text{.....(17)}$$

$$W_c = L_2S_cf\left\{\frac{R_1C}{2}\tan^{-1}\left(\frac{R_1}{C}\tan\alpha_1\right) - \frac{R^2{}_2}{2}\alpha_1 + \frac{A_1-A_2}{3A_1R_1\sin\alpha_1}\left[\frac{R_1C^3\cos\alpha_1}{(R_1^2-(R_1^2-C^2)\cos^2\alpha)^{1/2}} - R_1C^2 + R^3{}_2(1-\cos\alpha_1)\right] - \frac{1}{3R_0}\left[\frac{R_1^3C\sin\alpha_1}{(C^2+(R_1^2-C^2)\sin^2\alpha_1)}\,1/2 + R^2{}_2\sin\alpha_1\right]\right\} \quad \text{.....(18)}$$

This applies to one roll collar and should be multiplied by four for a "diamond" groove. In numerical

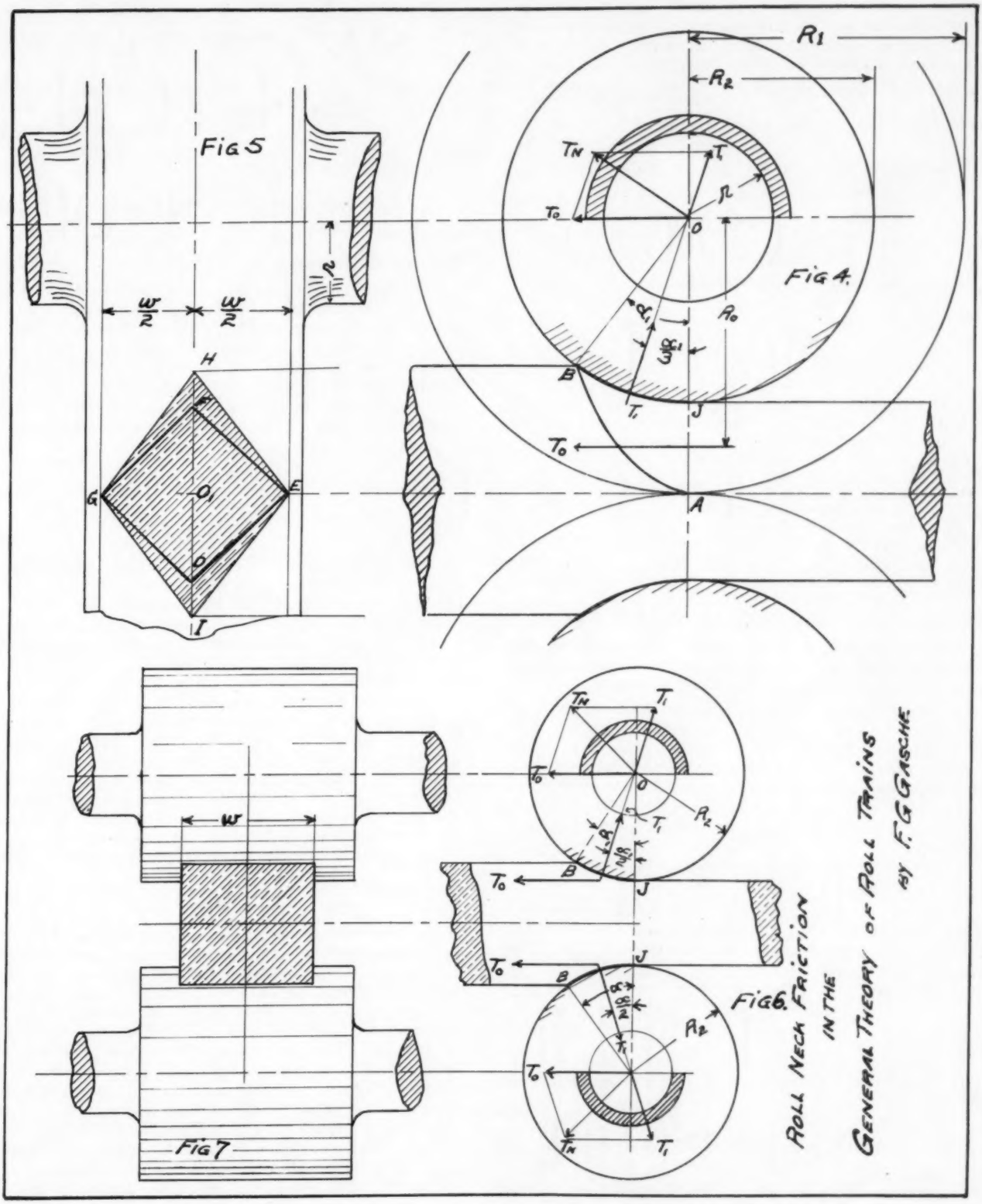


Fig 5
H
G
O1
O
E
I
W/2
W/2
r
Fig 4.
R1
R2
TN
T
T0
O
Ro
α1
β1
B
T1
J
A
W
Fig 7
Fig 6.
Roll Neck Friction
in the
General Theory of Roll Trains
by F. G. Gasche

substitutions the action represented by the terms involving A_1, and A_2 is frequently less than five per cent of the total resistance, especially for rectangular passes that do not require deep grooves in the rolls. The angle α_1, seldom exceeds 35 degrees such that the radian measure may be substituted for sine α_1. A further condensation of the formula (18) may be made by assuming the value of the ratio $K = \frac{C}{R}$ for the given pass. With these considerations we have approximately:

$$W_c = L_2 S_c f \left\{ \frac{KR_1^2}{2} \tan^{-1}\left(\frac{\tan\alpha_1}{K}\right) - \left(\frac{R_2^2}{2} + \frac{R_2^3}{3R_0}\right)\alpha_1 - \frac{KR_1^3}{3R_0}\frac{\frac{\tan\alpha_1}{K}}{\left[\left(\frac{\tan\alpha_1}{K}\right)^2 + 1\right]^{\frac{1}{2}}} \right\} \quad \text{.....(19)}$$

Again, assuming that the sine of the angle involved is sensibly equal to the radian value we may say, as a sufficient approximation:

$$W_c = \frac{L_2 S_c f}{6}\left\{\left(3 - 2\frac{R_1}{R_0}\right)\left[KR_1^2 \tan^{-1}\left(\frac{\tan\alpha_1}{K}\right) - R_2^2\alpha_1\right]\right\} \quad \text{.....(21)}$$

This applies to one collar and should be multiplied by four for a "diamond" groove. Other sections of the bar will indicate the number of collars.

Abrasions of Surfaces Parallel to the Roll Axis

As distinguished from collar action there are abrasions attending the use of square or rectangular grooves and open passes for bars, sheets and plates.

The elementary area of contact becomes $w^1 R_2 d\alpha$ instead of $RdRd\alpha$ as applied to a collar surface. It is assumed that $R_2 = R_0$ (See Fig. 6) though there is some evidence that the velocity of the delivery side of a bar may be in excess of the velocity of the roll surface. It may be a sort of detrusion of the plastic material of the rolled bar. In this case equation (7) becomes,

$$S = S_2\left[1 - \frac{\sin\alpha}{\sin\alpha_1}\left(1 - \frac{A_2}{A_1}\right)\right] \quad \text{.....(22)}$$

This represents the horizontal component of the velocity of the bloom surface at the point (R_2, α). The tangential velocity of this point in the direction of motion of the roll surface is,

$$S\cos\alpha = 2\pi n R_2 \cos\alpha\left[1 - \frac{\sin\alpha}{\sin\alpha_1}\left(1 - \frac{A_2}{A_1}\right)\right] \quad 23$$

The tangential displacement of the bloom surface is therefore:

$$ts\cos\alpha = 2\pi n t R_2 \cos\alpha\left[1 - \frac{\sin\alpha}{\sin\alpha_1}\left(1 - \frac{A_2}{A_1}\right)\right] \quad (24)$$

The relative displacement of roll surface and bar at the point (R_2, α) is (See equation 8)

$$V_r - ts\cos\alpha = 2\pi R_2 n t\left\{1 - \left[1 - \frac{\sin\alpha}{\sin\alpha_1}\left(1 - \frac{A_2}{A_1}\right)\right]\cos\alpha\right\} \quad \text{.....(25)}$$

$$= L_2\left\{1 - \left[1 - \frac{\sin\alpha}{\sin\alpha_1}\left(1 - \frac{A_2}{A_1}\right)\right]\cos\alpha\right\} \quad \text{.....(26)}$$

(The work done by abrasion through the distance $R_2 d\alpha$ is

$$dw = L_2 S_c f w^1 R_2\left\{1 - \left[1 - \frac{\sin\alpha}{\sin\alpha_1}\left(1 - \frac{A_2}{A_1}\right)\right]\cos\alpha\right\} d\alpha \quad \text{.....(27)}$$

from which, for one roll:

$$W_f = L_2 S_c f w^1 R_2\left[\alpha_1 - \frac{\sin\alpha_1}{2}\left(1 + \frac{A_2}{A_1}\right)\right] \quad \text{.....(28)}$$

Roll Neck Friction

The forces acting at roll necks lead to a considerable energy demand to overcome the journal friction. While the stresses applied to these bearings can be estimated with some degree of precision, the coefficient of friction is subject to such variation that calculated results may not correspond with actual working conditions in all cases. This class of journals operates in rare circumstances with a coefficient of friction as low as 0.10. From this up to the rubbing of dry cold surfaces at 0.20 or more to say nothing of the actual seizure of the metals, the frictional resistance is a considerable speculation. The advent of reliable antifriction bearings in comparatively recent times promises relief from a very annoying power demand of the usual mill practice and design.

Two forces, primarily, act on a roll with their resultants at roll neck bearings (See Figs. 4 and 6): First, a horizontal force T_0 acting parallel to the bloom axis and tangent to the circle of radius R_0. Second, a resultant force T_1 lying in a plane passing through the axis of the bloom and perpendicular to the axis of the roll. The force T_1 is, for "diamond" grooves, assumed to be directed toward the center O of the roll and along a line O T standing at an angle $\frac{\alpha_1}{3}$ with reference to the vertical line OA. This force is the resultant of all pressures exterted by the rolled bar on the conical collars and of the pressures acting on cylindrical surfaces within the roll groove. An exact estimate of this resultant T_1 would require analysis of such complexity that it is not justifiable in the presence of uncertainties concerning the coefficient of friction. The area upon which this resultant acts is assumed to be the triangle whose apex is the point B (see Figs. 1 and 3) and whose base is the line through the point J and parallel to the roll axis and of a length equal to w^1, the projected width of the bloom. In case of roll grooves having conical collars combined with cylindric surfaces the projected area of contact for the latter must be added to the triangular area as above prescribed. Let w^{11} be the

width of this cylindric position of the contact surfaces.

Then, with α_1 in radian measure, approximately,

$$T_1 = S_c R_2 \left(w^{11}\alpha_1 + w^1 \frac{\alpha_1}{2} \right) \quad \text{.....(29)}$$

The tangential force T_0 operating with a lever arm R_0 is derivable from the equation for all actions on the rolled bar in this manner, viz:

$$T_0 = \frac{w_t + w_c + w_f}{L_{r2}} \quad \text{.....(30)}$$

Referring to Fig. 4, the resultant of T_0 and T_1 acting at the center is—

$$T_n = \left[T_1^2 + T_0^2 + 2T_1T_0 \sin \frac{\alpha_1}{3} \right]^{\frac{1}{2}} \quad \text{.....(31)}$$

The energy expended on the friction of the necks of one roll is in foot pounds,

$$w_r = 2\pi n t f^1 T_n r = \frac{L_{r2} r f^1}{R_0} \left[T_1^2 + T_0^2 + 2T_1T_0 \sin \frac{\alpha_1}{3} \right]^{\frac{1}{2}} \quad \text{.....32}$$

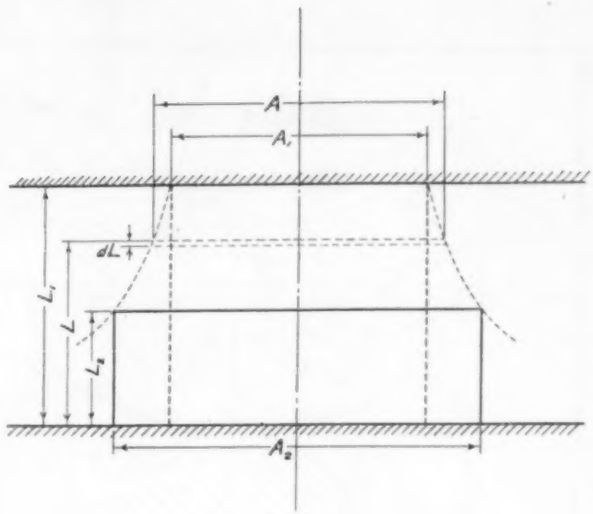
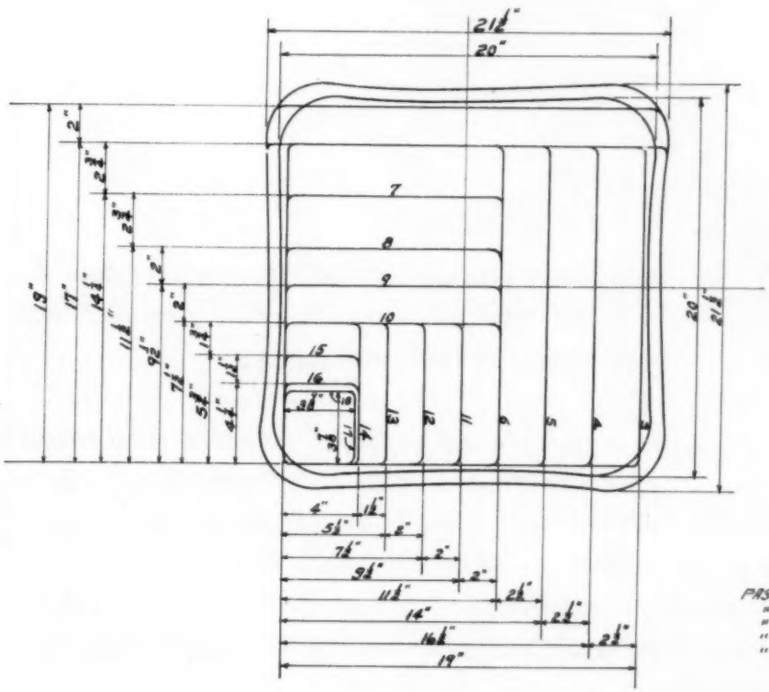


Fig. 8.

Pass No.	A_r	A_{r1}	$\frac{A_r}{A_{r1}}$	Distance between Rolls
1	443 382	408.5 355.0	1.085 1.085	19.0
2	408.5 380.0	367.5 340.6	1.111 1.117	17.0
3	367.5 340.0	223.0	1.137 1.052	19.0
4	323.0	280.5	1.151	15.5
5	280.5	238.0	1.178	14.0
6	238.0	195.5	1.217	11.5
7	195.5	163.9	1.192	14.25
8	163.9	132.3	1.239	11.5
9	132.3	109.3	1.211	9.5
10	109.3	86.3	1.267	7.5
11	86.3	71.3	1.210	9.5
12	71.3	56.3	1.267	7.5
13	56.3	41.3	1.354	5.5
14	41.3	30.0	1.366	4.0
15	30.0	23.0	1.304	5.75
16	23.0	17.0	1.353	4.25
17	17.0	15.0	1.133	3.875
18	15.0	15.0	1.000	3.875
19	BLIND	BLIND	1.000	STRAIGHT ENDS



PASSES 1 TO 6 INCLUSIVE ROLLED IN BULL HEADS PASS No 1
" 7 TO 10 " " " 12" " "
" 11 TO 14 " " " 8" " "
" 13 TO 16 " " " 4" " "
" 16 TO 19 " " " 4" " "

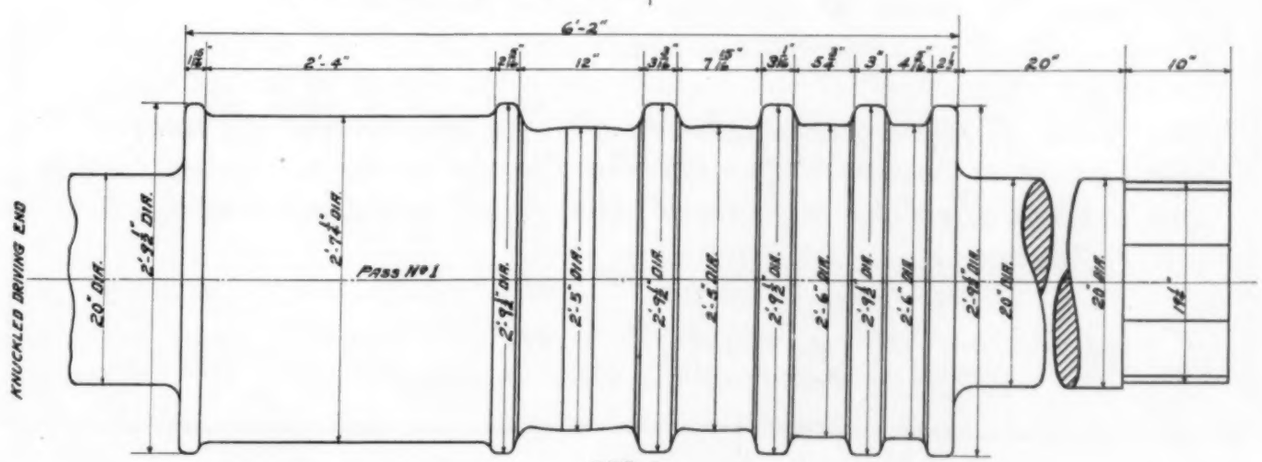
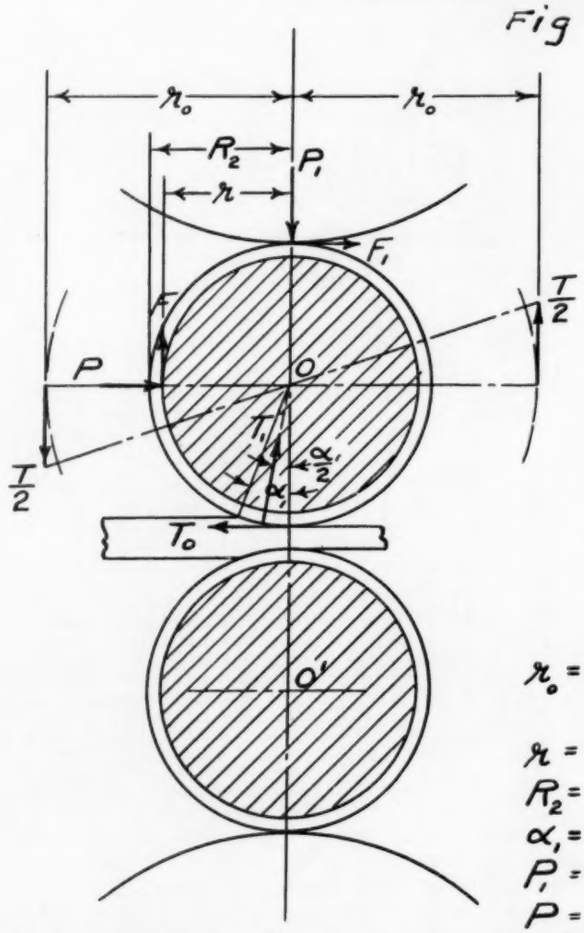


FIG. 9.

Distribution of Forces on the Center Rolls of a 4 High Plate Mill.

Fig 10.



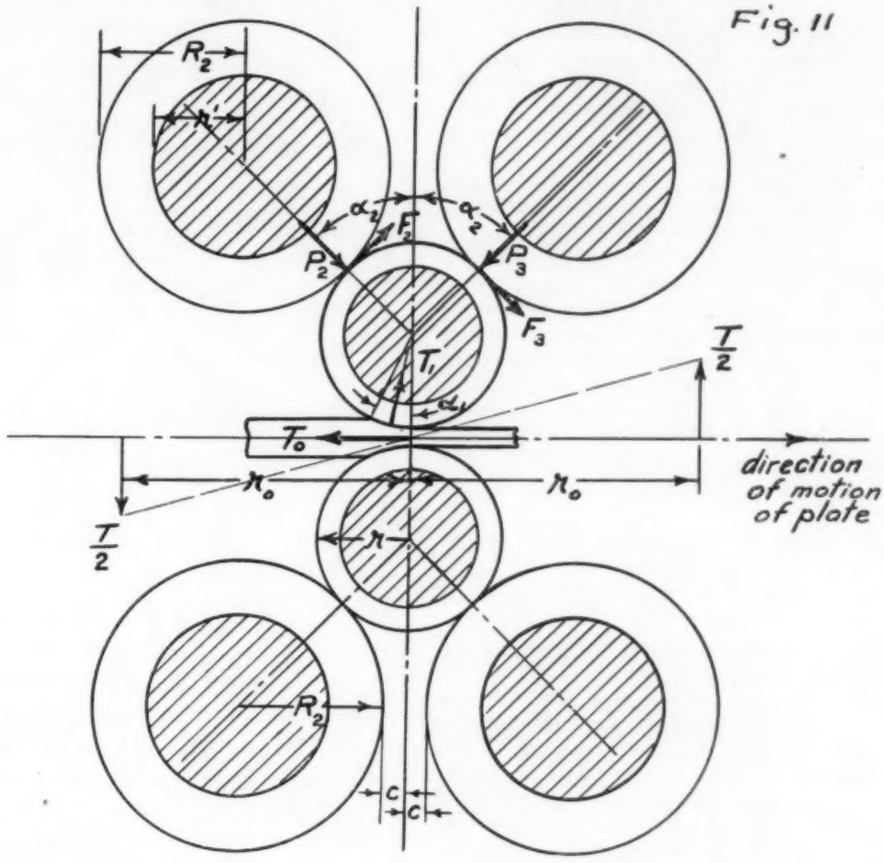
r_o = unit radius at which the torque T of the driving mechanism applies
r = radius of roll necks
R_2 = " " " surface
α_1 = angle of contact of rolls and plate
P_1 = reaction due to top (stiffening) roll
P = " " " middle roll bearings
T_1 = resultant of pressures of plate on middle rolls
T_o = tangential force at roll surface equivalent to roll action on the plate
Tr_o = moment of force, at one foot radius, exerted by driving spindles
F = tangential force at roll necks due to friction
F_1 = " " " " surfaces.

The force T_o is perpendicular to the line of centers. T_1 passes through O at an angle $\frac{\alpha_1}{2}$ with the line of centers. Both forces are established by a general theory of roll train resistance. (by F.G.Gasche)

f' = coefficient of roll neck friction
f'' = " " friction, rolling contact

Cluster Rolls for Sheet and Plate Mills

Fig. 11



r' = radius of idle roll necks
r_0 = unit radius at which the torque at unit radius applies
r = radius of active roll surface
R_2 = " " idle " "
P_2 = reaction of left idle roll
P_3 = " " right " "
T_1 = resultant of pressure of plate on middle (active) roll.
T_0 = tangential force at "active" roll surface due to equivalent roll action on the plate.
Tr_0 = moment of force at one foot radius exerted by driving spindle.
F_2 = tangential force at left "idle" roll surface.
F_3 = " " " right " " "
f = coefficient of friction of idle roll bearings.
α_1 = angle of contact of plate with active roll.
α_2 = " " idle roll center line with vertical.

The neck friction for open or flat passes like Fig. 6 and Fig. 7, would require the use of $\frac{\alpha_1}{2}$ in the place of $\frac{\alpha_1}{3}$ in equation (32) while a combination of conical collars and a cylindric portion of the pass will require further adjustment of the direction of action of the force T_1 and of the resultant T_n. There is no correction for the weight of the rolls in equation (32) for the reason of the predominance of other forces and the necessary approximations already suggested. Controversies develop concerning the division of the tractive effort T_0 between a pair of rolls, which if equal, would require the use of $\frac{T_0}{2}$ in the place of T_0 in the formula. The general impression seems to be that this is imposed on one mill spindle while the other through flexure, lost motion, and slippage lags behind the driving spindle and receives its motion from the rolled bar. The safest plan would be direct application of formula (32) to the roll connected with the driving spindle and the same formula with $T_0 = O$ for the necks of the companion roll.

Friction of Bearings and Mechanism of "Four High" Plate Mills and "Cluster" Rolls

The stresses applying to a "four high" stand of rolls (See Fig. 10) are largely influenced by the friction of the bearings of the outer or stiffening rolls, which are usually of larger diameter than the active or operating rolls. Their primary object is to prevent serious deflection in a direction perpendicular to the plate and variations of thickness of the latter. Owing to the magnitude of the tangential force T_0 there is at times a considerable lateral deflection of the driving operative roll which is not resisted by the stiffening rolls of the ordinary four high construction. The consequences of the lateral deflection of the active rolls are rapid wear of their surface and a particularly bad effect on the rolled plate known as "scarfing" or local tearing of its surface. It is easy to derive the tangential forces F, F_1, with known coefficients of friction at the necks of the rolls and at their contact surfaces with the evidence that a sufficiently high friction at the necks of the stiffening rolls may cause a slippage at their contact surfaces.

As a remedy for these operative and structural defects it is proposed to give both lateral and vertical support of each operating roll through the constraint of two larger idle rolls. (See Fig. 11). The arrangement is known as a "cluster" roll stand and provides its advantages chiefly through the opportunity to apply anti-friction bearings to the stiffening rolls. A few calculations will show the undesirable features of the "cluster" roll design if limited to ordinary plain bearings for the necks.

Four High Roll Stands (See Fig. 10.)

In the absence of suitable notation on this figure assume that:

R^1 = radius of idle or stiffening rolls.

r^1 = radius of idle roll bearings.

f^{111} = coefficient of friction of idle roll bearings.

we have,

$$F = Pf^1 \qquad \text{.....(33)}$$

$$F_1 = \frac{r^1}{R^1} f^{111} \qquad \text{.....(34)}$$

The three static equations are:

$$P_1 = T_1 \cos\frac{\alpha_1}{2} + F \qquad \text{.....(35)}$$

$$P = T_0 - T_1 \sin\frac{\alpha_1}{2} - F_1 \qquad \text{.....(36)}$$

$$Tr_0 = Fr + F_1R_2 + T_0R_2 \qquad \text{.....(37)}$$

Substituting from (33) and (34)

$$P_1 = T_1 \cos\frac{\alpha_1}{2} + Pf^1 \qquad \text{.....(38)}$$

$$P = T_0 - T_1 \sin\frac{\alpha_1}{2} - P_1 f^{11}\,\frac{r^1}{R^1} \qquad \text{.....(39)}$$

$$T = \frac{Prf^1 + P_1R_2\frac{r^1}{R^1} f^{111} + T_0R_2}{r_0} \qquad \text{.....(40)}$$

From these we get:

$$P_1 = \frac{T_0f^1 + T_1\left(\cos\frac{\alpha_1}{2} - f^1 \sin\frac{\alpha_1}{2}\right)}{1 + \frac{r^1}{R^1} f^1 f^{111}} \qquad \text{.....(41)}$$

$$= \frac{T_0 - T_1\left(\sin\frac{\alpha_1}{2} + \frac{r^1}{R^1} f^{111}\cos\frac{\alpha_1}{2}\right)}{1 + \frac{r^1}{R^1} f^1 f^{111}} \qquad \text{.....(42)}$$

Cluster Roll Stands (See Fig. 11)

If the entire group of rolls is in adjustment and acting on a plate there is no pressure on the bearings of active or middle rolls since they are completely supported by the idle rolls and the forces exerted by the plate. Taking the center of the top active roll as origin and the balanced system of forces,

$$T_1 \sin\frac{\alpha_1}{2} - T_0 + (P_2 - P_3)\sin\alpha_2 + (F_2 + F_3)\cos\alpha_2 = O. \qquad \text{.....(43)}$$

$$T_1 \cos\frac{\alpha_1}{2} - \left(P_2 + P_3\right)\cos\alpha_2 + \left(F_2 - F_3\right)\sin\alpha_2 = O. \qquad \text{.....(44)}$$

$$\left(F_2 + F_3\right)r + T_0r - Tr_0 = O. \qquad \text{.....(45)}$$

With a known coefficient of friction for the bearings of the idle rolls.

$$F_2 = \frac{r^1}{R_2} P_2 f \qquad \text{.....(46)}$$

$$F_3 = \frac{r^1}{R_2} P_3 f \qquad \text{.....(47)}$$

substituting these values in (43) and (44)

$$T_1 \sin\frac{\alpha_1}{2} - T_0 + \left(P_2 - P_3\right)\sin\alpha_2 + \frac{r^1}{R_2} f \left(P_2 + P_3\right)\cos\alpha_2 = O. \qquad \text{.....(48)}$$

$$T_1 \cos\frac{\alpha_1}{2} - \left(P_2 + P_3\right)\cos\alpha_2 + \frac{r^1}{R_2} f \left(P_2 - P_3\right)\sin\alpha_2 = 0. \quad \text{.....(49)}$$

Rearrangement and solution of the equations gives—

$$P_2 = \frac{T_1 \cos\frac{\alpha_1}{2}\left(\sin\alpha_2 - \frac{r^1}{R_2} f\cos\alpha_2\right) - \left(T_1 \sin\frac{\alpha_1}{2} - T_0\right)\left(\cos\alpha_2 + \frac{r^1}{R_2} f\sin\alpha_2\right)}{\left(\sin\alpha_2 + \frac{r^1}{R_2} f\cos\alpha_2\right)\left(\cos\alpha_2 + \frac{r^1}{R_2} f\sin\alpha_2\right) + \left(\cos\alpha_2 - \frac{r^1}{R_2} f\sin\alpha_2\right)\left(\sin\alpha_2 - \frac{r^1}{R_2} f\cos\alpha_2\right)} \quad \text{.....(50)}$$

$$P_3 = \frac{\left(T_1 \sin\frac{\alpha_1}{2} - T_0\right)\left(\cos\alpha_2 - \frac{r^1}{R_2} f\sin\alpha_2\right) + T_1 \cos\frac{\alpha_1}{2}\left(\sin\alpha_2 + \frac{r_1}{R_2} f\cos\alpha_2\right)}{\left(\sin\alpha_2 + \frac{r^1}{R_2} f\cos\alpha_2\right)\left(\cos\alpha_2 + \frac{r^1}{R_2} f\sin\alpha_2\right) + \left(\cos\alpha_2 - \frac{r^1}{R_2} f\sin\alpha_2\right)\left(\sin\alpha_2 - \frac{r^1}{R_2} f\cos\alpha_2\right)} \quad \text{.....(51)}$$

in the case where $\alpha_2 = 45°$ these become—

$$P_2 = 0.707\,\frac{T_1 \cos\frac{\alpha_1}{2}\left(1 - \frac{r^1}{R_2} f\right) - \left(T_1 \sin\frac{\alpha_1}{2} - T_0\right)\left(1 + \frac{r^1}{R_2} f\right)}{1 + \left(\frac{r^1}{R_2} f\right)^2} \quad \text{.....(52)}$$

$$P_3 = 0.707\,\frac{\left(T_1 \sin\frac{\alpha_1}{2} - T_0\right)\left(1 - \frac{r^1}{R_2} f\right) + T_1 \cos\frac{\alpha_1}{2}\left(1 + \frac{r^1}{R_2} f\right)}{1 + \left(\frac{r^1}{R_2} f\right)^2} \quad \text{.....(53)}$$

Application of the Theory to the Design of a Motor Drive for a 34-Inch Reversing Blooming Mill

In 1924 it was proposed to replace a reversing steam engine by a suitable electrical equipment. Opportunity developed for changing the size and shape of the ingot, modification of the rolls, and a considerable alteration of the rolling schedule, all for the sake of obvious advantages. Fig. (9) shows the surface contour of the rolls and an end view of the tapered ingot with lines superimposed thereon whereby the sectional dimensions of the ingot after each pass were specified. There were nineteen passes required to produce a billet from the ingot, the last two being straightening operations. The section diagram is so developed that the quarter turning of the ingot is directly shown with the consequent section of the ingot after the succeeding pass was completed. The tabulations give essential numerical values which enter into all subsequent calculations. The establishment of such a rolling schedule is possible through knowledge of the requirements of mill operations, which will not be amplified at this time, though it must not be concluded that any fanciful arrangement of passes, drafts and roll grooves will allow a highly efficient mill operation.

Accepting the rolling schedule as the operative requirement there is still the necessity of applying all the judgment that previous contacts and mill experience would make available in assigning suitable rotative speeds of rolls for each operation not to overlook the dominating character of the small time intervals between the passes and for general manipulations of the mill and the ingot.

On account of the taper of the ingot the first three passes impose a variable resistance to the rolls and driving mechanism. Average sections cannot be safely employed in numerical substitutions in the several formula, though mean values for torque and work may ultimately be applied when the service of a motor-generator set is to be specified.

Illustrative of this process the tabular statement; Appendix B, is attached with the observation that a complete numerical check could be possible only with the reproduction of memoranda concerning temperatures, fibre strength of steel and correction for inertia effects that entered the original work. This detail is inexpedient in view of the fact that each rolling mill is in fact a special problem.

It was estimated that the work required to produce billets from the ingot all as specified would be approximately twenty four kilowatt hours per ton measured at the switch board.

Actual operation of the mill after the attendants became familiar with all controls enabled the delivery of a ton of billets with twenty-three and three quarters kilowatt hours.

Strength and Stiffness of Rolls

The deflection of rolls under the condition of loading shown for Appendix C is of direct application to parts of four high stands (Fig. 10) and cluster rolls (Fig. 11). A proper allowance for the tangential force T_0 in addition to the force T_1 constituting the reaction on the roll surface. (Fig. 6) will lead to the magnitude and direction of the distributed load shown in Appendix C which must be used in estimating the roll deflection.

Concentrated loads like the groove loading of Appendix B, admit of ready calculation but the spring of the rolls is not so important as the cases above mentioned. With the length between centers of roll neck bearings shown in Appendix C, and with

the combined flexure and torsion due to forces T_0, T_1 as applied at the center of the roll length, Appendix B, the maximum fibre stress in the material of the roll at the bottom of the groove of a radius R_2 will be:

$$q = \frac{2}{\pi R_2^3}\left[\frac{T_1}{2}L + \left(\frac{T_1^2}{4}L^2 + T_0^2 R_2^2\right)^{\frac{1}{2}}\right] \quad \text{.....(54)}$$

pounds per square inch.

APPENDIX (A)

Relation of Tensile strength of steel and temperature as reported in "Iron Age" issues of May 7, 1903, and November 13, 1924, for temperatures 500° C, to 1200° C; 932° F, to 2191° F. Reported by Dr. Julius Koleman for No. VI and by P. Eyerman for Nos. I to V inclusive.

(Least squares adjustment of tests).

S_c = tensile strength pounds per square inch.
t = temperature degrees centigrade.
K, m, n = empirical consonants.

$$S_c = \frac{K - nt}{t - m}$$

Test

No.	Kind of Steel		Values of Constants K	n	m
I	Carbon Manganese	0.05% 0.45%	4497500.	508.6	418.0
II	Carbon Manganese	0.70% 0.40%	18800000.	13260.0	342.5
III	Carbon Manganese	1.40% 0.35%	31567000.	24100.0	162.5
IV	Chromium Nickel	1.00 3.00	27100000.	17300.0	245.0
V	High speed Tool Steel		12408500.	6117.6	623.5
VI	Medium Hard		12953700,	8074.0	200.1

Work Done in Twisting Plastic Bars

Many types of continuous mills involving simultaneous action of two or more roll stands on the same bar impose energy demands for twisting the bar beyond those attending simple roll action. The continuous mill generally requires a twisting of the bar through a right angle in a distance somewhat less than that between adjacent roll stands as applied by the guides, it requires a part of the equivalent tangential force acting along the bar resulting from the roll action. Two resistances develop from the use of such guides, viz: twisting, and guide friction.

The common theory of torsion of elastic bars involves a shearing stress on each elementary area of the section that is proportional to its distance from the neutral axis as compared with the distance to the surface elements. This assumption is convenient for the study of deformations produced by stresses within the elastic limit but it cannot be applied to stresses associated with the plastic state of the material. In the latter case we assume that the stress applied to each elementary area dF is of constant value S_c per unit of area. If the area dF is located at a distance ρ

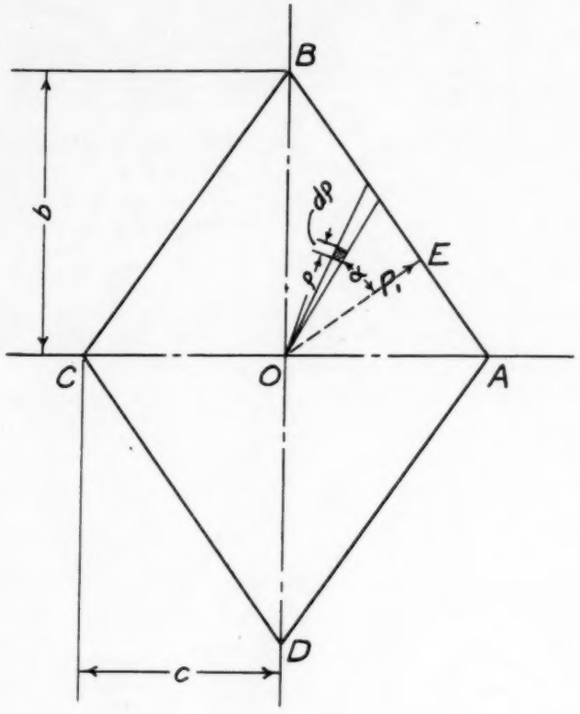


Fig. 12.

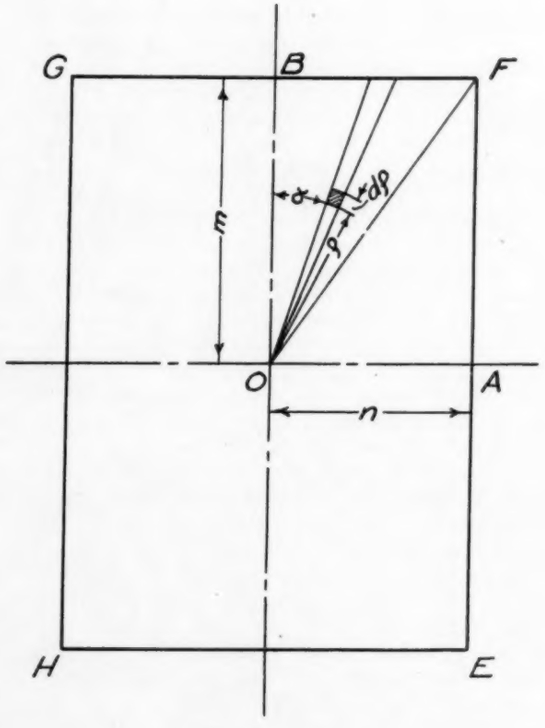


Fig. 13.

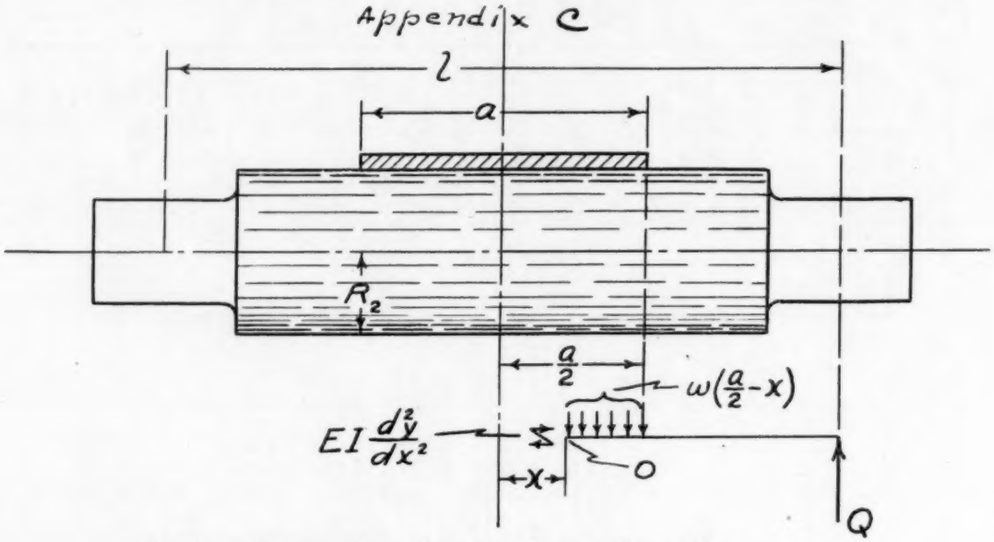
Appendix B

34" Blooming Mill Cycle — $21\frac{1}{2}$" × $21\frac{1}{2}$" × 70" Ingot into $3\frac{7}{8}$" × $3\frac{7}{8}$" Billets in 19 Passes

Pass Number			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Initial area of section	A_1	sq. in.	443 382	408 380	367 340	323	280	238	196	164	132	109	86	71	56	41	30	23	17
Final " " "	A_2	" "	408 380	366 340	323	280	238	196	164	132	109	86	71	56	41	30	23	17	15
Ratio of areas	A_1/A_2		1.085 1.055	1.111 1.117	1.137 1.052	1.151	1.178	1.217	1.192	1.239	1.211	1.267	1.211	1.267	1.364	1.366	1.304	1.353	1.133
Log of ratio	$\log_{10}$		0.0354 0.0022	0.0457 0.0480	0.0557 0.0220	0.0611	0.0711	0.0853	0.0763	0.0930	0.0831	0.1028	0.0828	0.1028	0.1348	0.1355	0.1153	0.1310	0.0542
Work due to elongation	W_e	ft. lbs.	1326000 82000	1711000 1798000	2086000 820000	2289000	2663000	3195000	2858000	3482000	3111000	3850000	3213000	3990000	5230000	5256000	4473000	5080000	2103000
Draft on each roll	d	in.	1.00 0.50	1.00 1.00	1.00 0.38	1.25	1.25	1.25	1.38	1.38	1.00	1.00	1.00	1.00	1.00	0.75	0.88	0.75	0.38
Width of bar	w'	"	20.5 18.0	20.0 21.5	17.0	17.0	17.0	17.0	11.5	11.5	11.5	11.5	7.50	7.50	7.50	7.50	4.00	4.00	3.88
Radius of roll surface	R_2	"	15.63	15.63	15.63	15.63	15.63	15.63	14.50	14.50	14.50	14.50	14.50	14.50	14.50	14.50	15.00	15.00	15.00
Arc of contact, radians	α_1		0.3607	0.3607	0.3607	0.4014	0.4014	0.4014	0.4392	0.4392	0.3723	0.3723	0.3723	0.3723	0.3723	0.3229	0.3403	0.3200	0.2240
" " " degrees	α		20°-40'	20°-40'	20°-40'	23°-0'	23°-0'	23°-0'	25°-10'	25°-10'	21°-20'	21°-20'	21°-20'	21°-20'	21°-20'	18°-30'	19°-30'	18°-20'	12°-50'
Final length of bar	L_2	ft.	5.90 6.30	6.55 7.09	7.46	8.59	11.25	12.32	14.70	18.20	22.04	27.92	33.80	42.80	58.35	80.30	104.75	141.70	160.70
Work due to abrasion	W_f	ft. lbs.	1846000 1206000	1997000 1068000	1887000 1946000	2460000	3190000	3475000	2880000	3604000	3616000	4533000	3750000	4700000	6800000	7480000	5744000	7310000	5730000
$W_e + W_f$		" "	3172000 1388000	3708000 2866000	3973000 2766000	4749000	5853000	6670000	5738000	7086000	6727000	8383000	6963000	8690000	11530000	12736000	10217000	12390000	7833000
$\frac{W_e + W_f}{L_2}$	T_0	lbs.	537000 220000	566000 405000	533000 371000	553000	520000	542000	390000	390000	310000	300000	206000	203000	100000	158000	100000	85000	52000
$S_c R_2 w' \sin \frac{\alpha_1}{2}$	T_1	"	388000 240000	379000 254000	322000 200000	365000	365000	365000	253000	250000	212000	213000	143000	143000	143000	124000	72000	68000	45000
Resultant on necks	T_n	"	494000 363000	495000 415000	442000 281000	487000	476000	483000	341000	339000	278000	275000	198000	197000	194000	154000	92000	84000	55000
Roll neck friction	W_n	ft. lbs.	560000 439000	671000 616000	682000 434000	876000	1108000	1332000	1040000	1276000	1268000	1586000	1384000	1744000	2340000	2560000	1922000	2686000	1760000
Total energy $E = W_e + W_f + W_n$		" "	3736000 1727000	4379000 3482000	4465000 3200000	5625000	6960000	8000000	6775000	8360000	8000000	10000000	8350000	10430000	12700000	15240000	12140000	15070000	9590000
Tangential force at rolls	T'	lbs.	633000 274000	670000 490000	624000 429000	655000	618000	650000	461000	459000	363000	358000	247000	244000	218000	190000	115000	106000	60000
" " " 1 foot	T	"	824000 357000	872000 640000	816000 558000	853000	805000	716000	557000	554000	446000	434000	299000	295000	264000	230000	144000	133000	74000
Speed of rolls		r.p.m.	15.	15.	20.	20.	30.	35.	40.	45.	50.	60.	70.	70.	80.	90.	100.	100.	110.
Time for pass		sec.	3.08	3.46	2.74	3.20	2.75	2.60	2.90	3.20	3.50	3.70	3.80	4.80	5.75	7.28	8.00	10.80	11.15
" " interval		"	3.50	4.00	3.50	3.00	3.00	6.00	4.00	4.00	4.00	6.00	5.00	5.00	6.00	5.00	5.00	5.00	5.00
Energy at D.C. Mill motors $\frac{E}{0.95}$		ft. lbs.	3550000 2870000	4610000 3670000	4900000 3370000	5920000	7320000	8420000	7100000	8800000	8420000	10520000	8780000	10970000	13370000	16050000	12770000	15850000	11000000
Torque at D.C. Mill motors $\frac{T'}{0.95}$		lbs.	666000 289000	706000 517000	653000 452000	690000	650000	684000	485000	483000	382000	377000	260000	257000	230000	200000	121000	112000	63000
Effective H.P. at motor shaft D.H.P.		H.P.	247.0 107.0	262.0 193.0	325.0 223.0	337.0	484.0	593.0	446.0	500.0	437.0	520.0	417.0	413.0	422.0	400.0	290.0	266.0	164.0
Total work to mill motors $\frac{E}{.90 \text{-} .93}$		ft. lbs.	3945000 3190000	5120000 4080000	4330000 3750000	6580000	8140000	9360000	7920000	9800000	9360000	11700000	9760000	12200000	14870000	17850000	14200000	17600000	12200000
Total work from D.C. Generators 98%		" "	4030000 3260000	5240000 4160000	4430000 3820000	6720000	8300000	9540000	8080000	9980000	9540000	11940000	9960000	12450000	15170000	18200000	14480000	17980000	12480000
Total work to D.C. Generators 90%		" "	4420000 3620000	5810000 4620000	6170000 4250000	7460000	9220000	10080000	8980000	10530000	10080000	13250000	10530000	13250000	16850000	20230000	16100000	19970000	13860000
Total input to A.C. motor shaft 95%		" "	4710000 3810000	6120000 4860000	6560000 4470000	7850000	9710000	11170000	9460002	11670000	11170000	13950000	11650000	14500000	17750000	21300000	16930000	21030000	14600000

Deflection of Steel Sheet Rolls

Appendix C



l = length, center to center of necks
a = width of sheet or plate
ω = pressure per inch of length of rolls
R_2 = radius of roll barrel
$I = \frac{\pi}{4} R_2^4$ = moment of inertia

Assuming that the pressure at the roll necks is applied to the middle of the length of bearing:
Taking origin at O, distance X from the vertical center line of rolls:

$$EI\frac{d^2y}{dx^2} = \frac{\omega}{2}a\left(\frac{l}{2}-x\right) - \frac{\omega}{2}\left(\frac{a}{2}-x\right)^2$$

$$= \frac{\omega}{2}\left[\frac{a}{2}\left(l-\frac{a}{2}\right) - x^2\right]$$

$$EI\frac{dy}{dx} = \frac{\omega}{2}\left[\frac{a}{2}\left(l-\frac{a}{2}\right)x - \frac{x^3}{3}\right] + (c=0)$$

$$EIy = \frac{\omega}{2}\left[\frac{a}{4}\left(l-\frac{a}{2}\right)x^2 - \frac{x^4}{12}\right]$$

$$= \frac{\omega}{8}x^2\left[a\left(l-\frac{a}{2}\right) - \frac{x^2}{3}\right]$$

when $x=\frac{a}{2}$, $y = \frac{\omega}{32EI}a^2\left[al - \frac{7}{12}a^2\right]$

$$= \frac{\omega}{32EI}a^3\left[l - \frac{7}{12}a\right]$$

Note: when $x=\frac{l}{2}$, this reduces to the common formula $y_1 = \frac{5}{384}\cdot\frac{\omega l^4}{EI}$

from the center of the bar section, and $d\alpha$ is the small angle included between its radial boundries then $dF = \rho d\rho d\alpha$ (See Fig. 12). The shearing force applied to this area is,

$$S_c \rho dF = S_c \rho^2 d\rho d\alpha \qquad \text{.....(55)}$$

The couple which is equivalent to the torsional resistance of the bar is,

$$Pa = S_c \int\int \rho^2 d\rho d\alpha \qquad \text{.....(56)}$$

The particular contour of the section will establish the limiting values of ρ and α though most of the mill products involve rectangular or "diamond" sections for which the integrals will be given.

For convenience in calculating the resistance of the section like Fig. 12 it is divided into eight triangles. Four of these are equal and similar to BOE while there are four equal and similar to AOE. Considering BOE the extreme values of ρ lying on the line BA are thus related

$$\rho \cos\alpha = P_1 \qquad \text{.....(57)}$$

$$\text{and } \varphi(\rho) = \frac{P_1}{\cos\alpha} \qquad \text{.....(58)}$$

For this triangle,

$$S_c \int_0^{\varphi(\rho)} \int_0^{\alpha_1} \rho^2 d\rho d\alpha = S_c \int_0^{\alpha_1} \left[\frac{\rho^3}{3}\right]_0^{\frac{P_1}{\cos\alpha}} d\alpha = S_c \int_0^{\tan^{-1}\frac{b}{c}} \frac{P_1^3}{3\cos^3\alpha}\, d\alpha$$

$$= \frac{S_c P_1^3}{6}\left[\frac{\sin\alpha}{\cos^2\alpha} + \log_e \tan\left(\frac{\alpha}{2}+\frac{\pi}{4}\right)\right]_0^{\tan^{-1}\frac{b}{c}}$$

$$= \frac{S_c P_1^3}{6}\left[\frac{b}{c^2}(b^2+c^2)^{\frac{1}{2}} + \log_e\left(\frac{(b^2+c^2)^{\frac{1}{2}}}{b}+\frac{c}{b}\right)\right] \qquad \text{.....(59)}$$

In the same manner, by substituting the complement $\frac{\pi}{2} - \alpha$ for the angle α we have for the triangle AOE,

$$Pa = \frac{S_c P_1^3}{6}\left[\frac{c}{b^2}(b^2+c^2)^{\frac{1}{2}} + \log_e\left(\frac{(b^2+c^2)^{\frac{1}{2}}}{b}+\frac{c}{b}\right)\right] \qquad \text{.....(60)}$$

The total torsional resistance of the section (Fig. 12) is four times the sum of (59) and (60) being the equivalent of (56).

For the rectangular section (Fig. 13) having sides of length 2m and 2n the torsional resistance as determined in the preceding manner is,

$$Pa = \frac{2}{3} S_c \left\{2mn(n^2+m^2)^{\frac{1}{2}} + m^3 \log_e\left(\frac{(n^2+m^2)^{\frac{1}{2}}}{m}+\frac{n}{m}\right) + n^3 \log_e\left(\frac{(n^2+m^2)^{\frac{1}{2}}}{n}-\frac{m}{n}\right)\right\} \qquad \text{.....(61)}$$

The total angle of torsion, generally exceeding one rev olution for the entire length of the bar L_2 is represented by Δ radians. The work done in twisting a bar of th is length and having a rhomboidal (diamond) section is,

$$\Delta Pa = \frac{2}{3} S_c P_1^3 \Delta \left[(b^2+c^2)\frac{b^3+c^3}{b^2c^2} + \log_e \left(\frac{b^2+c^2}{bc} + \frac{b-c}{bc}(b^2-c^2)^{\frac{1}{2}} - 1\right)\right] \qquad \text{.....(62)}$$

For rectangular sections this becomes, equation (61) multiplied by Δ; for square sections this reduces to $\Delta Pa = 1.8448 \Delta S_c m^3$ ——(63)

Association of Iron and Steel Electrical Engineers

Proposed

Crane Specifications

To Be Discussed at 26th Annual Convention Being Held at Buffalo, New York, June 16-20, 1930

1. Explanation

This Specification is intended to cover, in general, the requirements for all types of cranes. Copies will be furnished to manufacturers for reference but will not be issued with each request for quotations. This specification will be made a part of the specific information furnished Bidder by Purchaser, and Order or Contract stating special features, sizes, etc., of cranes to be purchased. All cranes for special service, such as soaking pits, strippers, ore bridges, gantries, etc., shall so far as possible comply with the requirements of this Specification.

Where features are specified to be AS REQUIRED, it is understood that the requirements covering such features are to be given in the specific information furnished Bidder by Purchaser. Where such information is not given or if this Specification offers an option, Contractor shall furnish material according to his judgment. Features not covered by this specification, or the specific information furnished Bidder by Purchaser, shall be in accordance with Contractor's standard or with what is known as good practice among Crane Manufacturers.

2. Specifications

This Specification shall be known as the Association Iron and Steel Electrical Engineers Crane Specification. It shall be referred to in all contracts as such and shall form part of such contracts, when so stated, whether attached to same or not. Builders Specification shall be known as Contractor's Specification.

Sheets issued by different works stating sizes, special features, requirements, etc., shall be known as PURCHASER'S INFORMATION SHEETS. Where the requirements of these Information Sheets differ from Specification, the former shall take precedence.

Sheets to be filled in by Bidder showing specific data in regard to apparatus he proposes to furnish, shall be known as CONTRACTOR'S INFORMATION SHEETS.

Where Contract covers a number of cranes, this Specification shall apply to each and every one.

In addition to Specifications furnished with proposition, Contractor shall furnish two (2) copies of his specification for the Work's file.

3. Propositions

Bidder shall submit his Specification in triplicate and return three (3) copies of Purchaser's Information Sheets and Agreement signed together with three (3) copies of Contractor's Information Sheets giving the required data in duplicate in the two columns, otherwise bids will not be considered. No alternative propositions will be considered unless accompanied by a proposition in strict accordance with these Crane Specifications. Additional blank Contractor's Information Sheets will be furnished on request to Bidder desiring to submit such alternative propositions.

Bidder shall also submit with his proposition such description, prints, etc., as shall be necessary to give full understanding of the general construction and special features of all apparatus included in his proposition, also prints showing general dimensions.

4. Changes

Purchaser reserves the right to make such changes in Specification or specific information as may be necessary after Contract is signed.

Any difference in cost resulting from such changes shall be agreed upon before work is begun on same.

5. Delivery

Crane to be delivered f.o.b. cars at Manufacturer's plant with freight allowed Purchaser's Works.

6. Erection

Erection shall be entirely done by Contractor, by Purchaser, or erected or started under the supervision of Contractor's Superintendent, AS REQUIRED.

Where erection is required by Contractor or Purchaser, all work shall be performed by party specified without recourse to the other party.

Where erection is required under supervision of Contractor, he shall furnish without expense to Purchaser a competent man to superintend the complete erection of crane. Purchaser will furnish all other labor, tackle, etc., required. The Superintendent of Erection shall arrange the work so the erecting crew shall be kept employed to the best advantage during their working hours, otherwise the loss of time will be charged against Contractor; he shall also be responsible for all accidents or damage to persons or property during the erection of, and until the work under this Contract is completed and equipment put into regular service.

Where apparatus is required to be started under Contractor's supervision, he shall furnish without expense to Purchaser, a competent man to check up all work and superintend the starting of the crane.

Contractor shall pay the cost of all fitting or changes made in the field which are rendered neces-

sary by his failure to have done such work correctly in the shop before shipment.

7. Guarantee

Contractor shall guarantee to successfully perform the work as outlined and required in this Specification, and to pay all costs of removing, renewing and installing any part or parts which may prove defective in design, material or workmanship before acceptance and within one (1) year after the date crane has been put in operation.

8. Test and Acceptance

Test shall be at the maximum working load of the crane as regards speeds, and such tests must show compliance with the requirements.

Acceptance shall be subject to compliance with these Specifications and Information Sheets, to be determined by inspection after delivery by results of tests above required and upon the approval of Purchaser's Representative.

In case of disagreement between Contractor and Purchaser's Representative in regard to the interpretation of any specification or the compliance of the apparatus furnished with the requirements of this Specification, the question shall be submitted to the engineering department of the purchasing company, whose decision in all such cases shall be final.

If crane is found not to comply with this Specification, the Contractor shall be notified to that effect and shall be required to make apparatus meet the Specification as quickly as possible. Contractor shall proceed with the work within ten days from date of such notice, and if he fails to do so within the time specified, Purchaser reserves the right to make crane comply with the Specification at the expense of the Contractor.

9. Patents

Contractor agrees to pay all royalties on patents embodied in this work, and agrees to assume the defense of any suit or suits for infringement of a patent or patents which may be brought against Purchaser by reason of the use of any apparatus furnished by Contractor, and to indemnify said Purchaser from all loss by damage or costs which may result from a decree or injunction against Purchaser in said suit or suits.

10. Drawings

The Bidder shall submit with proposition, drawings showing general arrangement and detail construction of crane. Immediately after receipt of order and before proceeding with the work, Contractor shall submit to Purchaser for information and criticism a complete set of prints, duplicate of those from which the crane is to be built, but such approval is not to be considered as relieving the Contractor from responsibility. Contractor shall furnish Purchaser two complete sets of correct detail working prints and general arrangement on cloth as seen as work has been completed and checked. It is agreed that prints thus furnished will be confidential and will not be exhibited to other crane builders, also that contract shall not be considered as completed or final payment be due until such drawings have been furnished to Purchaser.

11. Strength of Material and Factor of Safety

Proper provision shall be made for all parts subject to impact and rough usage.

Journals and shafts shall be of sufficient size to bring bearing pressures and deflections within safe and practicable limits.

Fiber stress in cast iron shall in no case exceed 2,000 pounds, in tension, or 8,000 pounds in compression.

Fiber stress in cast steel shall in no case exceed 8,000 pounds in tension or 10,000 pounds, in compression.

The physical properties of structural work shall be governed by the Manufacturers' Standard Specifications.

All apparatus not otherwise noted shall be designed throughout with not less than the following factors of safety under full load, based on ultimate strength of material used:

All hooks, etc., not less than	Ten (10)
All gears and complete hoist mechanism	Eight (8)
Ropes for mill crane, not less than	Five (5)
Ropes for hot metal handling crane	Five to Ten (5 to 10)
Structural Steel and all other parts, not less than	Five (5)

Calculations for wind pressure on outside cranes shall be based on not less than 30 pounds, per square feet of exposed surface, and on 45 pounds where exposed to storms.

All castings shall be of steel unless otherwise specified, of best material and free from blow holes or other injurious defects.

If purchaser desires a special type of collector shoe, he shall supply builder with drawings of same.

12. Workmanship, Material and Inspection

Workmanship and material shall be first class in every respect, and subject to the inspection of Purchaser's Representative at all times.

Contractor shall furnish Purchaser's representative with full information concerning the material entering into the construction of this work.

13. Interchangeability

As far as practical, corresponding parts of crane shall be alike and interchangeable.

14. Accessibility

All parts, which may require occasional removal or replacement shall be readily accessible.

In order to change a shaft, a motor, or a bracket, it shall in no case be necessary to move any part keyed in place, another shaft, motor or bracket.

All lubricating devices shall be conveniently located.

15. Painting

All parts of the crane to be held in contact by bolts or rivets shall not be painted before assembling.

All structural work and other unfinished parts shall be cleaned thoroughly and given two coats of paint; this is to be done on inaccessible parts before assembling, immediately after inspection.

All track wheels, gears, shafting and other machined surfaces shall be properly slushed.

Conductor bars to be painted yellow with the exception of contact surfaces.

16. Tool and Supply Boxes

Each crane shall be supplied with ⅛" thick sheet steel tool box, of ample size, with hinged lid, fastened to girder side of footwalk, near the landing of ladder or steps.

Each tool box shall be equipped with a full set of jaw wrenches to fit all nuts and bolts on crane and all special socket wrenches for couplings.

Box for storing oil, grease and waste, made of steel plate and provided with hinged lid, shall be fastened to girder side of foot-walk.

17. Safety Devices

In addition to the safety appliances, such as limit switches, footwalks, gong guards, toe angles, railings, etc., as specified herein, Contractor shall supply all appliances necessary to make the crane comply with the latest Factory Laws of the State in which it is to be operated.

Hoist limit switches shall be mounted directly over the hoisting ropes, so that no sheave wheels are necessary, unless specific permission has been obtained from the purchaser for other type of mounting.

It is recommended that Electrically Operated Track Sanders operated from the cab by the crane operator, shall be provided for sanding the runway rails.

18. Clearances

Prints showing building clearances will be furnished with Purchaser's Information Sheets. Not less than four inches actual clearance shall be allowed between highest part of crane and roof chord, and not less than 2½" inches actual clearance between any other part of crane and building columns or other stationary structure, where new cranes are installed in old buildings.

For the safety of the men whose duty requires them to work arround the crane it is strongly recommended that at least 18 inches be allowed between end of crane and the face of building column and not less than 18 inches between top of crane and bottom of roof truss in designing new buildings.

19. Bridge Girders

Bridge girders shall be standard type used by crane builders, single structural shape, riveted or welded, AS REQUIRED.

Top and bottom cover plates and angles of box section girders should preferably be in one piece throughout the girder length, but splicing of approved design may be allowed.

Web plates to be not less than 5/16" thick.

The top cover plate of Box girders carrying rails shall be supported at frequent intervals by structural steel distance pieces, which shall bear against it and be riveted or welded to both web plates.

Diaphrams to be provided backing up bridge motor supports over full depth of girder and riveted or welded to these supports and web plates.

Hand-holes to be put in outside web plate near top of girders, to make bolts for rail clamps accessible.

Girders shall be rigidly riveted or welded to end trucks, and be provided on bottom with gusset plates which shall be as large as possible without interfering with the trolley travel.

To further assist in keeping crane "square" and stiff, a heavy angle with foot walk plate, shall be riveted or welded across top of girders at extreme ends, and the entire end of girders covered by a plate riveted or welded to this angle, to vertical angles on end of web plates and riveted or welded to end carriages.

Box Girders shall be drained to prevent accumulation of oil and water, holes to be not less than one inch in diameter.

Where required, a permanent structure supporting beam or beams for use in repairing trolley, shall be located over bridge motor and arranged to allow of its use for repairs on that motor.

This structure shall be capable of lifting the heaviest renewable piece on trolley.

Capacity of each hoist shall be shown in pounds on each side of crane in such a manner as to be easily legible from the floor.

Outrigger girder to be installed to support footwalk and bridge motor.

20. Bridge End Carriages

End carriage shall be of cast steel or structural steel, welded, AS REQUIRED, and duplicate with flanges turned out to allow easy access to rivets, and be made amply strong to prevent breakage, under most severe strains resulting from legitimate use of crane.

They shall, where practicable, have bearings on both sides of driving pinions integral with the end carriage.

There shall be a heavy safety lug or strap across the bottom of each carriage near the track-wheel and one inch above the top of rail, to prevent excessive drop in case of breakage of track-wheel, axle or carriage. Wheel base shall not be less than ten (10) feet and must be of ample length on long span cranes.

No part of carriage or track-wheel gears shall project below the flange of track-wheel.

End carriage to be so designed as to permit of easy changing of the wheels.

Pads shall be provided for use of jacks or wedges when changing track wheels.

Safe means must be provided to give access to compensating trucks and track wheels from track girders.

Guards which will push forward or off the track any object placed across it, like a persons foot or arm, shall be attached to each end of the carriages.

Safe means must be provided to get on the bridge of crane from the crane runway.

21. Bridge Drive

Track-wheels shall be driven through gears keyed to their axles or hubs, and pinions keyed to line shaft, which shall run full length of girder and shall be supported by ample number of bearings.

Shafts shall be divided into section, AS REQUIRED, none to exceed twenty (20) feet in length.

End sections to be duplicates.

Track-wheel gears should be inside of end-carriage wherever possible.

Bridge motor supporting brackets shall be of structural material with plate web, and having attachment angles extending the full depth of girder,

and over top and bottom cover plate angles riveted or welded to girders.

All track wheels to have taper tread. This taper to be 1" to 16" on the radius or 1" to 8" on the diameter. The small diameter of the track-wheel to be on the outside of the crane. The width of the tread, or distance between flanges, of the track-wheel to be at least 1½" greater than the head of the rail.

22. Operator's Cab

All cabs shall be built of structural steel and fireproof material, not less than seven (7') feet high and of dimensions required.

They shall be made substantial and rigid by proper gusset plates and braces welded or riveted, but such bracing shall not interfere with access to cab or vision of operator.

Cab shall also be braced to opposite girders or outrigger girder.

All shall be provided with water tight plate roofs, which shall not slope towards front.

Floor shall not be less than 3/16" steel and shall be extended to form a landing platform, which shall be equipped with handrail and toe angle similar to foot-walks and where practicable stairway to foot-walk above shall be located on this platform.

Ladle cranes and other cranes having cabs subjected to heat from below shall have not less than 3/16" steel shield, six inches below floor proper attached by bolts, having spacing sleeves on them.

Covering of cab floors shall be specified by the Purchaser.

Each cab shall be provided with a conveniently located steel hand or foot operated gong, not less than 12" in diameter, or other suitable warning signal appliance.

Open cabs shall have toe angles around floor, angle to extend not less than six inches above floor coverings.

Enclosed cab shall be weather proof, covered with plate and be provided with windows on three sides, which drop completely out of sight and are protected from breakage by a ⅛" sheet steel shields, which if on the inside, shall extend to within two inches of top of floor.

All window sash shall be of metal and equipped with clear glass, shatter-proof glass preferred.

23. Trolleys

Side frames shall be of cast or structural steel, riveted or welded, AS REQUIRED, and shall be tied together by steel cross girts, and the requirements for bridge end-carriage regarding safety lugs and clearances shall be same as for the side frames.

Where practicable, all brackets and bearings shall be permanently attached to frames.

Drum bearings and support for upper sheaves shall be located so as to equalize the load on track-wheels as nearly as possible.

For protection of workmen underneath, not less than 5/16" steel plate, with openings for ropes and toe angles around edges and openings, shall extend underneath the entire trolley.

Trolley to have floor plate under motors, shafts, drums, etc., forming a working platfrom with provision made for reaching foot-walk on either side of frame.

On cranes for handling molten metal, where the main hoist drums carrying two sets of ropes are driven by two motors, each through its own train of gears each motor and set of gears must be capable of handling the full load independent of the other.

24. Drums

All drums shall be keyed to shaft on driving gear end, and shall be designed so as to leave not less than two complete wraps of hoisting rope in grooves when hook is at lowest position, and not require over-lapping of rope when hook is in highest position.

Drums shall have turned grooves of depth equal to one-half the diameter of the rope, and pitch at least ⅛" greater than this diameter.

Shaft shall be increased in diameter not less than twice the depth of the key seat where attached to drum, or gear.

Drums shall be preferably of steel and have flanged ends of a depth and thickness to suit the size of cable but not less than 1" thickness projecting 2½" beyond body of drum.

Pitch diameter of drum shall be that required by the rope manufacturer for size and kind of rope used, but not less than 30 times the diameter of the hoisting rope.

Where use of lifting magnet is specified, there shall be provided a drum covered with hard wood or similar insulating material, with collector rings for handling magnet cable.

Collector rings to be mounted on a cast spider with double insulation; duplicate brushes to be provided to prevent opening of magnet circuit.

Magnet cable shall be attached at center of drum which must be sufficient length to permit winding of magnet cable in either direction.

Weather protection shall be provided for magnet cable drum on cranes for outdoor service.

25. Ropes

Ropes shall be of quality and size recommended by Rope Manufacturer as suitable for the service required.

Where double ropes are provided for safety or for double drive, each rope shall have the same capacity that would be required if only one rope were provided.

Instead of the usual equalizing sheave, equalizing bar may be provided, AS REQUIRED, to which is to be attached the ends of the hoist cables. Equalizing bar to be provided with an anti-friction bearing.

25a. Sheaves, Equalizers and Blocks.

Sheaves shall be bronze bushed or provided with anti-friction bearings and have finished grooves not less than two times the diameter of the rope.

Sheaves shall have a pitch diameter that will comply with the recommendations of the rope manufacturer, but not less than 30 times the diameter of the rope and shall be protected by guards, which fit close to the flanges so as to prevent rope coming off.

Bottom block shall be of structural steel and plates or steel castings, as far as possible, entirely enclosed, and hook shall swivel on ball or other anti-friction bearings so constructed as to exclude dirt.

Hooks shall be of steel forgings, designed for a

safe load of not less than 200% of the full capacity of the hoist.

Top sheaves should be provided with cable guards to prevent cable from coming off sheaves.

All parts of block shall be so arranged as to be readily lubricated, grease fittings being so located as to be protected from injury as far as practical.

26. Automatic Limits

All hoists shall be provided with dependable, automatic normally closed cutouts, preferably with dynamic braking to prevent over-travel of hook in lifting, AS REQUIRED.

All gantry cranes subject to damage due to excessive misalignment shall be provided with safety limit switches on bridge motion, to provide for this contingency.

Wherever possible crane safety limit switches should be located directly over the hoisting rope so that no sheave wheels need be used.

When advisable, automatic devices should be provided to prevent cranes from running away under wind pressure.

27. Track Wheels

All track wheels shall be rolled or forged from high carbon Open Hearth steel, unless cast steel wheels are specifically permitted by the purchaser.

They shall not be less than 1½" wider than the rail on which they run and shall be finished to a taper of 1" in 16", the center of tread being the specified diameter of the wheels, and mounted with the large diameter of wheel toward center of crane.

Flanges shall not be less than ⅝" thick by ⅞" deep, not including fillets and the tread shall be of sufficient thickness to carry rated load when wheels have been reduced 1½" diameter.

The standard diameter of bridge track wheels shall be 18, 24, 27 and 30" and no rail lighter than 85# shall be used.

The standard bores of these wheels shall be as follows:

18-inch diameter	4⅝-inch bore
24-inch diameter	5⅝-inch bore
27-inch diameter	6⅝-inch bore
30-inch diameter	7⅝-inch bore

A standard increase in diameter of ⅛" for all bridge track wheel axles in the wheel seat is recommended.

All bridge track wheels on same crane to be interchangeable.

The maximum load on any one track-wheel with trolley fully loaded and at adjacent end of bridge shall not exceed 70,000 pounds, except by written consent of Purchaser, nor shall there be over 650 lbs. per square inch, of projected area on any track-wheel bearing.

The standard tread diameters of trolley track wheels shall be 12, 15, 18, 21 and 24".

The standard bores of these wheels shall be as follows:

12-inch diameter	3⅛-inch bore
15-inch diameter	3⅝-inch bore
18-inch diameter	4⅝-inch bore
21-inch diameter	5⅛-inch bore
24-inch diameter	5⅝-inch bore

29. Bumpers

Each end of each bridge end-carriage shall be equipped with a substantial bumper of compression spring type, located above rail center line.

Bumpers shall be of sufficient length to prevent any part of either crane being injured when bumpers of two cranes come together.

Trolley bumpers to be of compression spring type, to be attached to bridge girders, and located so as to engage lugs attached to trolley frame.

Where two trolleys are operated on the same bridge, they shall be equipped with spring bumpers on their adjacent ends.

Bumpers to be equipped with safety chains or cables, to prevent them from falling to the ground when knocked loose.

30. Rails

All rails shall be first quality American Standard "T" section, of size required.

Joints shall be made by means of standard splice bars, and provision shall be made to prevent creeping of rails on girders by means of plate riveted or welded to the cover plate or by welding rail itself to cover plate.

Rails shall be fastened in place by steel clamps and through bolts, or welded, spaced not more than 36 inches on centers, and those on one side shall have a lead of at least three inches over those on the other side.

The trolley rails shall be not less than 66 pounds section.

31. Foot-Walks

Unless otherwise specified steel foot-walks with rough tread, not less than ¼" thick and 24" wide shall be provided on outside of both girders, extending to web of the girders and full length of crane, and where practicable, over end carriages and cab making it continuous around top of crane.

Where only one such foot-walk is installed on the crane, it shall be on the side carrying the bridge motor.

When motor is not located entirely below floor of walk, the walk shall be widened at the motor to give a clearance of not less than 15 inches between railing and motor.

Where motor is located partly or entirely below foot-walk it must be surrounded by a plate corresponding to the foot-walk.

Where practicable, walk or girders shall have not less than 6 feet, 6 inches clearance below roof-chord.

Both sides of foot-walks shall be provided with toe angles which shall extend at least 4" above top of walk, and be not less than 5/16" thick.

Where practicable, a structural foot-walk of same general design shall be provided around entire trolley.

31a. Railings.

Railings shall be provided for foot-walks, preferably made of structural steel, shall be of standard construction, not less than 42 inches high, with toe boards not less than 4 inches high, with intermediate member 21 inches high. Where pipe is allowed no threads shall be cut or threaded fittings used.

Railings shall be provided on girder foot-walks, ends of bridge, landing on cab, and on stairs leading to bridge girder from landing on cab.

31b. Stairs and Ladders

Where necessary, steps or ladders, steps preferred, shall be provided to give easy access to girders, end carriages, cab and trolley.

Stair treads shall be of material designed to prevent slipping, and shall not be less than 18 inches in width. Where stairs are not constructed with risers, a plate shield shall be attached to the under side, extending the entire length.

Where ladders must be provided they shall be of steel and constructed with square rungs to prevent turning. The rails shall extend 42" above landing place at top, for safety in getting on or off the ladder.

Where the slope of stairs exceeds angle of 55 degrees from the horizontal, ladders shall be used preference to stairs.

All foot-walks, railings, ladders, or steps, shall be made so as not to interfere with the removal of any part of crane.

32. Castings

All castings shall be made of best material, sound and free from blow holes, shrinkage cracks or other defects. Defective castings shall not be patched or welded without consent of Purchaser's Representative.

34. Brackets

Bearing brackets, if not cast integral with frame, must be kept in alignment by male and female joints or other equally effective method.

No body bound bolts shall be used nor shall bolts be depended on for aligning brackets.

Duplicate brackets are to have holding bolt holes drilled and keys finished to template so as to be interchangeable.

Tie brackets in a single cast piece shall be provided to tie all driving and driven shafts, and shall be located as close as possible to pinion and gear.

Where brackets or other finished parts are attached to structural material, unless such material is of sufficient thickness to allow for finishing, heavy planing strips shall be riveted or welded to structure, which is to be assembled and finished.

Heavy caps shall be provided with eye bolts for lifting.

35. Bearings

All track-wheels not equipped with Anti-friction Bearings shall be provided with M. C. B. type boxes, having hard bronze linings arranged so that they can be lined up to compensate for wear, and provided with large steel oil pockets or cellars filled with waste.

All bearings, unless Anti-friction bearings are used, except those on motors, sheaves and M. C. B. type, shall be split horizontally and fitted with caps finished male and female accurately bored out, and lined with split hard bronze bushings with flanges on either side to prevent same from falling out, and held from turning by heavy lugs cast on top half.

Bottom half of sleeve bearing shall be so designed as to permit of its removal and renewal without removing shaft and shall be designed to allow for lining up, to compensate for wear.

Bearing pressure on track-wheel brasses shall not exceed 650 lbs. per square inch, except by written consent of Purchaser.

Where Anti-friction bearings are used on crane track-wheels, the trucks shall be accurately machined for the bearing cartridges so that there will be no misalignment. Where these bearings are used on hoist and trolley shafting the trolley shall be preferably a one piece casting with brackets cast integral or a welded trolley so as to permit accurate machining. Where these bearings are to be used in connection with a structural trolley, the brackets shall be welded to frame and then bored out for the bearing cartridges.

Bearing pressures on Anti-friction bearings shall not exceed that allowed by the manufacturer of the bearing used.

36. Lubrication

Screw feed Compression grease cups, or fittings for high pressure lubricating system, shall be furnished for all sleeve bearings. Master Car Builders' type, motor bearings and bearings supplied with ring oilers are excepted.

Cups shall be of not less than 6 ounces capacity for shafts 3 inches and over, in diameter, 3 ounces capacity for shafts 2 inches and under, in diameter and shall be screwed into holding lugs in top half of bearing bushing with ½" standard pipe thread.

When grease cups are used, means shall be provided for preventing them from falling, due to becoming unscrewed or broken off.

They shall, as far as possible, be located at points accessible from foot-walks.

Type of grease cups to be specified by Purchaser if there is a preference.

High pressure fittings must have not less than ½" standard pipe thread.

Where more than one sheave wheel is located on a shaft, each sheave wheel must be provided with individual means of lubrication.

37. Gears and Pinions

All gears and pinions shall be cut to diametrical pitch, Brown and Sharpe standard involute teeth, or 20° "Stub", as required, nothing under 4 Pitch being used.

All gears and pinions, under 12" diameter, shall be forged of Open Hearth steel unless otherwise specified.

All motor gears shall be rolled or forged steel of sizes, as required.

The rim of all gears must be at least equal to the thickness of the teeth, at the pitch line.

No split gears shall be allowed.

Overhung gears, other than armature pinions, shall be used only in exceptional cases, with Purchaser's approval.

The builder shall use the motor manufacturers' standard gear ratios.

Drum gears shall be keyed to the periphery of drum, which must not be reduced more than 1" in diameter where gear is attached.

38. Couplings

The standard A. I. & S. E. E. coupling shall be used, so designed that the same coupling can be used on all sizes of line shafting from 3⅜ to 4½" diameter inclusive.

It shall have a straight face, a 10" circle and six 1" holes for body bound bolts.

This coupling for safety reasons must be covered by a guard.

Couplings shall be located as close as possible to brackets.

39. Gear Covers

All gears shall be completely covered or guarded by covers, firmly and substantially attached to brackets or other parts of crane, and shall have sufficient clearance to prevent their being struck by any of the enclosed parts, and shall be oil tight.

Covers shall be in two pieces, split horizontally, and so fastened and arranged that top half can be removed for inspection and repairs without disturbing bottom half.

Directly above the mesh line of the teeth, there shall be hand-hole, with cover held closed by spring hinge.

Gear covers may be cast, but should preferably be of sheet steel, not less than ⅛" thick, welded inside and outside at corners, and shall be provided with lugs or other means for lifting.

40. Shafting

The diameter of all shafting shall be in even ½" sizes except that 3⅜" shafting will be accepted.

The minimum diameter of bridge line shafting shall be 3⅜".

End sections of bridge drive shaft shall be 4 feet long and interchangeable.

Middle section shall be at least 8 feet long.

All shafting shall be increased in diameter in ⅛" increments, to twice the key-seat, depth for a distance equal to the length of the hub fit, for gears, pinions, track-wheels or drums and a generous fillet being provided except when these are located at the end of the shaft.

All shafting 6 inches diameter and under, not having swells or increases, shall be rolled or drawn; all above that diameter shall be forged and turned to size.

Diameter of all motor axle shafts shall be as required.

All shafting having increased diameters for hub bearings, and all shafting above 6 inches diameter, shall be forged and turned to size.

41. Force Fits

All connections subject to torsion shall be pressed or shrunk on and keyed in place.

Press fits shall be made with a pressure of not less than ten tons per inch of shaft diameter.

43. Bolts, Nuts and Rivets

All bolts, cotter pins, except those in couplings shall be rough machine bolts and all bolts shall have U. S. Standard thread, with cold pressed hexagon nuts.

They shall be provided with cotter pins, lock nuts and spring lock washers, and heads held from turning by recess or projecting lugs, where specified cotter pins should be provided.

No studs, cap-screws or body bound bolts, except on couplings shall be used without the written consent of Purchaser's representative, after detailed explanation of the necessities has been made.

No bolts, except those used in safety flange couplings, shall be so located as to require the use of socket or other special wrench.

In all structural work, such as gusset plates, brackets supporting foot-walks and bridge-line shaft, angles supporting operator's cab and all other parts, unless welded, rivets shall be used instead of bolts, wherever possible.

44. Brakes

Brakes complying with the following requirements shall be supplied, AS REQUIRED:

A. Mechanical retaining brake.

B. Electro-dynamic braking control.

C. Magnet brake on commutator-end extension of armature shaft.

D. Auxiliary magnet brake located on shaft as close as practicable to drum.

E. Foot operated brake on commutator-end extension of armature shaft, with foot-lever conveniently located for operator, and arranged to be fastened in "on" position.

F. All brake supports, except for Auxiliary Brakes shall be mounted on motor base-plate.

Each brake shall be capable of retarding full load, lowered at twice the hoist speed, and holding same when stopped, unassisted by other brakes.

Brake wheels shall be web form, finished all over and accurately balanced.

Face of wheels shall be double flanged to center the brake-band where same is used.

Brakes for same size motor shall be alike, and interchangeable.

D.C. solenoids shall be single spool, with coil wound on heavy cast shell and protected from the weather by metal casing.

Winding shall be of fireproof insulated wire or strap, which in case of series coils shall have cross section not less than that of the motor fields with which they are in series with an allowable temperature rise equal to that of the motor fields no round wire larger than No. 1 B.&S. gauge will be used.

A.C. coils shall be single phase, have fireproof insulation throughout and be held rigidly on cores.

Means shall be provided to prevent any parts of brake from falling to the ground in case they become detached, or broken.

Mechanical retaining brake, if specified shall preferably be screw friction type of liberal area, simple in design so as to necessitate minimum attention, and of sufficient capacity to absolutely prevent load from lowering unless motor is revolved by power in the lowering direction.

Unless otherwise specified, and where direct current is used, lowering shall be by electro-dynamic control, with one magnetic brake on armature shaft of hoist motor.

Where electro-dynamic brake is required, lowering speed with full load on hook shall be limited to twice the normal full load speed of armature.

With 100 lbs. pressure on foot lever, bridge footbrakes shall stop crane within a distance in feet equal to 10% of full load speed in feet per minute when traveling at full speed with full load.

Where operator travels with the trolley, on cranes or charging machines, a shunt or series wound brake, as specified, must be installed on the bridge motor.

Where cranes are equipped with anti-friction bearings a series brake must be installed on the trolley motor.

45. Conductors

Conductors across the bridge shall be of rigid type.

Main conductors and collectors for longitudinal travel of cranes will be furnished and installed by Purchaser.

Trolley cross travel conductors and collectors shall be furnished and installed by Contractor, AS REQUIRED.

Conductors shall be located preferably above girders along foot-walks on opposite side of bridge motor so that hoisting rope cannot come in contact with them under any operating condition, and shall be of a section, AS REQUIRED.

46. Motors

In no case shall the rating be less than that determined by the use of the American Institute of Electrical Engineer's Standards for Railway Motors, which shall be the basis for determining the sizes unless motors are specified by the Purchaser.

They shall be provided with feet and the contractor shall furnish the motors with axle bearings to support the jack shaft or motors without axle bearings equipped with flexible coupling and gear reduction in oil tight gear box, as specified.

No pinion shall be located on commutator end of shaft, except with consent of Purchaser.

All bearings shall be ring-oiling, or Anti-friction bearing, AS REQUIRED, and armature shafts shall be provided with standard extensions, straight or tapered, AS REQUIRED, whether equipped with brake-wheel or not.

All motors shall be mounted horizontally.

All bolt holes in feet shall be supplied with bolts.

When practicable, motors shall be arranged so that sufficient clearance is allowed, when changing armature, to swing top half of motors on their hinges.

47. Controllers*

Controllers may be furnished by Purchaser, AS REQUIRED, in which case all data regarding same necessary to design cab, foot-walk, conductors, supports, etc., will be supplied to Contractor by Purchaser.

Purchaser may specify or approve type, make and size, of motors and controllers to be used.

Where controllers are located on foot-walk, Purchaser should state whether cranes are under cover or exposed to weather so that proper provision can be made to protect same.

Controllers must be equipped with unbreakable resistance.

*Guide forms for ordering controllers for Crane Service may be obtained from the office of the Association of Iron and Steel Electrical Engineers, if desired.

48. Wiring

Wiring, switchboard, and all other electrical apparatus may be furnished by, and all wiring be done by the Purchaser.

Purchaser shall submit wiring specifications, where the contractor is to wire up the crane.

All cranes must be equipped with an enclosed double pole safety switch, mounted on the foot-walk adjacent to the cab, and be so connected that it will disconnect the main circuit between the collectors and the switchboard.

A protective switchboard panel shall be provided, unless the protective apparatus is included on the individual panels.

Location and type to be specified by the Purchaser.

APPENDIX A
HOT METAL CRANES

1. For Cranes Handling Hot Metal the Following Additional Specifications Shall Apply.

2. Operator's Cab

(A) Operator's Cabs shall be so constructed that in case of spills the operator may completely enclose himself by means of doors, and steel protecting shields over the windows.

(B) When crane is handling molten metal and no provision is made for the quick escape of operator, by runway or other means, in case molten metal gets spilled, there shall be provided a compartment for operator to get into that will resist unbearable heat for at least ten minutes.

The door to such compartment shall be at least 18" wide and it must be so attached that it can be tightly closed.

(C) Cab that will be subject to heat from below, shall have a shield plate not less than 3/16" thick, 6" below floor of cab, attached by bolts having spacing sleeves on them.

PROPOSED

ASSOCIATION OF IRON AND STEEL ELECTRICAL ENGINEERS CRANE SPECIFICATIONS

.....WORKS....., 19.....

SERIAL NO.....

SPECIFIC INFORMATION COVERING ELECTRIC CRANES

(This information to be furnished Bidder by Purchaser)

Contractor shall furnish.....Electric Cranes of.....lbs. capacity.

No proposition will be considered which does not comply with all the requirements of the attached agreement.

Item numbers in the following are the same as corresponding section numbers of the General Crane Specifications.

General		
	Number of cranes	
	Where used	
	Duty	
	Building clearances, Drawing No.	
Capacity		
	Maximum working load of:—	
	Main hoist	lbs.
	First auxiliary hoist	lbs.
	Second auxiliary hoist	lbs.
Dimensions		
	Span center-line to center-line to bridge runway rails	
	Total lift of main hoist	
	Total lift of first auxiliary hoist	
	Total lift of second auxiliary hoist	
	Minimum distance from center-line of main hoist hook to center-line of bridge rail on cage end.	
	Minimum distance from center-line of first auxiliary hook to center-line of bridge rail on cage end	
	Minimum distance from center-line of second auxiliary hook to center-line of bridge rail on cage end	
	Minimum distance from center-line of main hoist hook to center-line of bridge rail on side opposite cage	
	Minimum distance from center-line of first auxiliary hook to center-line of bridge rail on side opposite cage	
	Minimum distance from center-line of second auxiliary hook to center-line of bridge rail on side opposite cage	
Speeds		
	Full load speed of main hoist	
	" " " " first auxiliary hoist	
	" " " " second " "	
	" " " " bridge	
	" " " " main trolley	
	" " " " auxiliary trolley	
6.	**Erection**	
	Crane shall be erected by	
19.	**Bridge Girders**	
	Is structure over trolley to be supplied?	
20.	**Bridge End-Carriages**	
	Cast or structural steel? Welded or Riveted	

21. Bridge Drive
Length of sections to be as follows:—

22. Operator's Cab
Open or closed

Kind of floor

Special features

23. Trolley
Is side frame to be of cast or structural steel?
Welded or Riveted

24. Drums
Is lifting magnet used on crane?

25. Ropes, Sheaves and Blocks
Kind of rope

Hooks to be in accordance with print No.

26. Automatic Limits
Style automatic limits

30. Rails
Size rails bridge runway

Size rails main trolley runway

Size rails auxiliary trolley runway

35. Bearings
M. C. B. type bearings to be furnished on

Compression grease cups to be furnished on

Anti-friction to be furnished on
Oil-rings to be furnished on

37. Gears and Pinions (Pitch and No. of teeth)
Main hoist motor

First auxiliary hoist motor

Second auxiliary hoist motor

Bridge motor

Main trolley motor

Auxiliary trolley motor

38. Couplings
All couplings in accordance with print No.

40. Shafting (Motor Axle)
Main hoist motor Dia.

First auxiliary hoist motor Dia.

Second auxiliary hoist motor Dia.

Bridge motor Dia.

Main trolley motor Dia.

Auxiliary trolley motor Dia.

42. Keys
Keys and keyways in accordance with print No.

44. Brakes (type of brake and brake lining)
Main hoist

First auxiliary hoist

Second auxiliary hoist

Bridge

Main trolley

Auxiliary trolley

45. Conductors
For type of conductors, supports and collectors, see Drawing No.

46. Motors
Standard enclosed crane motors of following types and sizes to be furnished:

Main hoist

First auxiliary hoist

Second auxiliary hoist

Bridge

SERIAL No..... ....., 19.....

SPECIFIC INFORMATION COVERING ELECTRIC CRANES

(This information to be furnished Bidder by Purchaser)

Main trolley

Auxiliary trolley

47. Controllers
Controllers shall be furnished by

48. Wiring
Wiring, switchboard and other electrical apparatus shall be furnished by

49. Special Features

.....WORKS ....., 19.....

SERIAL No..... SERIAL No.....

SPECIFIC INFORMATION COVERING ELECTRIC CRANES

(This information to be furnished Purchaser by Bidder)

Complete set of information sheets to be filled out by Bidder in the two columns for each different size and kind of crane bid upon

	Column 1	Column 2
General		
1. Bidder		
2. Date of proposition		
3. Total weight of crane exclusive of motors		
4. Total price f. o. b. Purchaser's works		
5. Price per lb. exclusive of motors		
6. Time of delivery in weeks		
Clearances		
7. Total height of trolley above trolley runway rail		
8. Distance of trolley runway rail to bridge runway rail		
9. Distance from center between bridge girders and extreme outside of cage		
10. Distance from center between bridge girders and extreme outside of crane on side opposite cab		
11. Minimum center to center distance of two of these cranes on same runway		
12. Distance from top of trolley runway rail to bottom of cab		
13. Minimum safe working distance between top of trolley runway rails and highest point of main hoist hook		
14. Minimum safe working distance between top of trolley runway rails and highest point of first auxiliary hoist hook		
15. Minimum safe working distance between top of trolley runway rail and highest point of second auxiliary hoist hook		
NOTE Bridge runway rail on cab end to be called "A," on opposite end to be called "B"		
16. Minimum distance center of main hoist hook to center of rail "A"		
17. Minimum distance center of main hoist hook to center of rail "B"		
18. Minimum distance center of first auxiliary hoist hook to center of rail "A"		
19. Minimum distance center of first auxiliary hoist hook to center of rail "B"		

SERIAL No..... ....., 19.....

SPECIFIC INFORMATION COVERING ELECTRIC CRANES

SERIAL No.....

(This information to be furnished Purchaser by Bidder)

	Column 1	Column 2
Bidder		
20. Minimum distance center of second auxiliary hoist hook to center of rail "A"		
21. Minimum distance center of second auxiliary hoist hook to center of rail "B"		
22. Distance between center of main and first auxiliary hoist hooks		
Girders		
23. Type of girders (Box, I or Lattice) Riveted or Welded		
24. Number of girders		
25. Distance center to center of girders		
26. Maximum deflection of girders with full loads (all hoists) at center of bridge span		
27. Weight of bridge complete without trolleys		
End-Carriages		
28. Type of end-carriage (cast or structural) Riveted or Welded		
29. Number of track-wheels on one carriage		
30. Diameter of track-wheels		
31. Wheel base (two wheel carriage)		
32. Wheel base of outside wheels (four wheel carriage)		
33. Wheel base of inside wheels (four wheel carriage)		
34. Weight of end-carriage complete		
35. Maximum load on one end-carriage wheel		
36. Size of end-carriage wheel bearings		
37. Maximum pressure per square inch on track-wheel brasses		
Bridge		
38. Diameter of bridge line shaft		
Main Trolley		
39. Is trolley reversible?		
40. Type side frame (cast or structural) Riveted or Welded		
41. Diameter of track-wheels		
42. Wheel base		
43. Span		
44. Total weight		
45. Maximum load on one wheel		
46. Maximum pressure per square inch on track-wheel brasses		
Auxiliary Trolley		
47. Is trolley reversible?		
48. Type side frame (cast or structural) Riveted or Welded		
49. Diameter of track-wheels		
50. Wheel base		
51. Span		
52. Total weight		
53. Maximum load on one wheel		
54. Maximum pressure per square inch on track-wheel brasses		

SERIAL No..... ....., 19.....

SPECIFIC INFORMATION COVERING ELECTRIC CRANES SERIAL No.....

(This information to be furnished Purchaser by Bidder)

		Column 1	Column 2
	Bidder		
Main Hoist			
55.	Number of drums		
56.	Diameter of drums		
57.	Total number of gear reductions		
58.	Minimum diameter of sheaves		
59.	Diameter of rope		
60.	Total length of rope (if rope is in more than one piece, give length of each piece and number of such pieces)		
61.	Number of ropes supporting load		
62.	Approximate speed, light load		
First Auxiliary Hoist			
63.	Number of drums		
64.	Diameter of drums		
65.	Total number of gear reductions		
66.	Minimum diameter of sheaves		
67.	Diameter of rope		
68.	Total length of rope (if rope is in more than one piece, give length of each piece and number of such pieces)		
69.	Number of ropes supporting load		
70.	Approximate speed, light load		
Second Auxiliary Hoist			
71.	Number of drums		
72.	Diameter of drums		
73.	Total number of gear reductions		
74.	Minimum diameter of sheaves		
75.	Diameter of rope		
76.	Total length of rope (if rope is in more than one piece, give length of each piece and number of such pieces)		
77.	**Number of ropes supporting load**		
78.	**Approximate speed light load**		

SPECIAL RAILROAD FARES—A. I. & S. E. E. CONVENTION AND IRON AND STEEL EXPOSITION

BUFFALO, N. Y.—JUNE 16th to 20th

TO OUR MEMBERS, EXHIBITORS AND FRIENDS;
ASSOCIATION IRON & STEEL ELECTRICAL ENGINEERS:

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Recent Developments in Industrial Furnace Design

By G. R. McDermott*

This paper is concerned with Industrial Furnaces employed for reheating of ingots, blooms, slabs, billets, and rounds in steel plants. The past few years have witnessed radical improvements in the design and consequently the performance of such furnaces.

G. R. McDERMOTT

As "necessity is the mother of invention", so the increasingly rigid requirements of steel purchasers have forced a re-vamping of conversion methods in steel practice. In order to meet the ever-increasing exactness of the specifications of the trade, more attention had to be given, among other things, to the quality of steel heating. There are three major factors for consideration in analyzing this situation:

First: Improvement of quality of product as a result of superior heating;

Second: Increased production;

Third: Economy.

The third item may in turn be considered from the standpoint of three factors, namely: Operation; Maintenance; and Fuel Consumption. Obviously, these items are dependent to a great extent upon quality and production.

The steel makers have played their part in fostering our present prosperity by increasing the quality and quantity of their output, while at the same time reducing prices and raising wages. Old mills were electrified to increase their capacity and thereby effect savings in fuel and labor per ton. Continuous rolling methods to process in one single step were substituted for old methods requiring greater labor cost. In every case, the importance of the reheating unit was suddenly thrown into the lime-light by necessity. Let us review what has been accomplished and, next, how it was done.

It is obvious that certain heating requirements are being performed today that a few years ago would have been considered impossible. A prominent example is the uniform heating of wide slabs in continuous furnaces for rolling into wide strip by the continuous process developed by The American Rolling Mill Company. For example, on one wide strip mill 3″x36″x78″ slabs have been rolled to 0.035″ thickness on a production basis with a uniform gauge and perfect quality of product. Exhaustive metallurgical tests, both in this country and on the continent, have established the fact that such results are dependent upon an absolutely uniform heat of 2150 to 2250° F., with a thin, free scale.

At one time, while a member of the Combustion Committee of the Association, it was suggested that a set of rules, or standards, be adopted whereby furnace performance could be compared on an equitable and justifiable basis. With this in mind, we propose in our discussion of soaking pits and heating furnaces to employ the following terms as a basis for comparing furnace performance:

For heating furnaces:

Pounds per square foot of effective hearth area, or pounds per square foot of exposed surface, i.e., ratio of pounds of steel heated per furnace hour to square foot of stock surface exposed to top heat.

B.t.u. per ton, i.e., ratio of calorific value of heat in-put from fuel to long tons of steel heated.

Thermal efficiency, i.e., ratio of heat out-put in steel to total heat in-put to furnace by fuel.

For soaking pit furnaces:

Tons per hole hour, i.e., ratio of long tons of steel heated per hour to the total number of holes, or single pits, in operation.

Pounds per square foot of hearth area, i.e., the ratio of pounds of steel heated per hour to square foot of hearth area.

B.t.u. per ton, i.e., ratio of calorific valuet of heat in-put from fuel to long ton of steel heated.

In comparing the heating rate of two separate installations, it is obvious that the pounds per square foot of exposed surface will not necessarily give a fair check of their productive efficiency. The type of steel heated, the fuel used, the method of charging and discharging the furnace, the presence or absence of water-cooled parts, the effective length of the furnace, and the number of points from which it is fired, will all have a direct bearing on the heating rate. However, for comparison of general types of furnaces, we have found this term most effective.

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In the consideration of soaking pit furnaces, it would be very difficult to get an actual measure of thermal efficiency unless the furnace was constantly charged with cold steel. Features which influence the capacity of a soaking pit furnace quite materially are: Ratio of the total individual pit wall surface to single pit volume; Ratio of total ingot volume to single pit volume; and Ratio of square feet of exposed heating surface to ingot volume.

In considering fuel economy and production, it is instructive to compare the figures quoted by Professor Trinks in 1923 as fair practice in fuel efficiency and heating rates at that time with results obtained on furnaces constructed within the past few years.

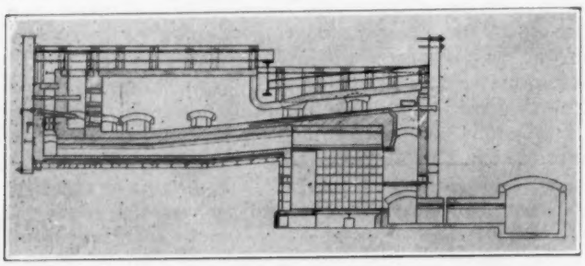

FIG. 1.

For continuous rolling mill furnaces, he quotes an average thermal efficiency of approximately 33%, and a heating rate from cold to rolling temperature of from 50 to 80# of steel heated per square foot of furnace hearth area.

Figure 1 shows a cross-section through a furnace with a heating rate of 120# of steel per square foot of hearth area, and a thermal efficiency of approximately 50%. This furnace is of the side charge side discharge type. The billets ride on steel skids imbedded in the brickwork for a portion of their travel down the hearth. The soaking hearth at the discharge point is made of chrome material. The furnace is fired with raw producer gas at approximately 900° F. at the burners. The air for combustion is preheated by means of a refractory tile recuperator.

Approximately 20% of the total combustion air is provided by a fan. This air is used to aspirate the hot air from the recuperator through an alloy venturi tube. The mixture of air partially aspirates the producer gas through the venturi-shaped burner block. The reduction in the air temperature does not affect the efficiency of the burner, as the design was based on giving the mixture temperature which would obtain the desired flame temperature in the combustion chamber. The matter of air preheat and flame temperature is a feature which we will discuss later in this paper, but we would like to point out at this time that until recently there has been considerable tendency to "put the cart before the horse",—that is, to expect greater furnace efficiency with higher air preheat. It is obvious that, with such a fuel as producer gas giving a highly luminous flame and having relatively high sensible heat, we are limited with regard to the air preheat which can be utilized as regards flame temperature and propagation. Practical results have indicated that it will vary from 500 to 1000° for continuous heating furnaces and soaking pits working on producer gas, depending upon the type of port employed and the analysis of the steel to be heated.

It will be observed that two sets of burners are provided on this furnace. The lower set is used for conditioning the steel and protecting it from oxidation and equalizing the temperature. These burners are operated with a slightly reducing atmosphere. With the lower burners protecting the steel on the hearth, it is possible to fire the upper burners at a maximum rate and obtain a high rate of production without injuring the steel. This furnace is heating material for a 10" Continuous Mill. The billets run from 1¾" to 3" in thickness and up to 42'-6" in length. This particular furnace is supplied by gas from a single producer, so that it becomes a simple matter to determine the fuel consumption of the furnace. Observations made to determine the economic results indicate over a week's period an actual consumption of 129# of coal per long ton of finished product. On a yield basis of 91%, this is equivalent to 117.2# per long ton heated.

It is interesting to note that the results obtained on the furnace described above show a marked improvement in capacity and fuel economy over a furnace constructed but three years previously, in which a low velocity port rather than a burner type of construction was employed and a smaller space for combustion was provided. A four-day test run on the latter furnace indicated a heating capacity of 108# per sq. ft. of effective hearth area per furnace hour and a fuel consumption of 148.5# of coal per gross ton heated. It is well to add that the two furnaces compared are of approximately the same effective length and slope of hearth.

The improvements which have been made in furnace design has naturally had a marked effect upon furnace maintenance. The refractory maintenance on the furnace shown in Figure 1 has been considerably lower than on the other furnace. The refractory manufacturers have contributed their share by improving the quality of their product. The larger furnace combustion volume provided in recent furnaces has decreased the B.t.u. release per square foot of wall surface. The beneficial results have manifested themselves in the increased life of the furnace refractories, when referred to the roof and side walls.

The production and fuel consumption figures quoted above were, of course, based on the most efficient type of furnace from the standpoint of heating cost. In the heating of wide slabs for continuous strip mill practice, it has been necessary to develop a far more elaborate design.

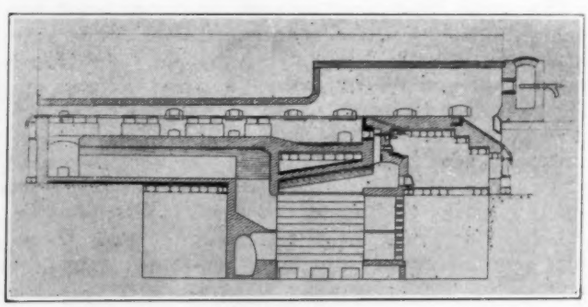

FIG. 2.

Figure 2 shows a furnace of the end charge end discharge type fired with coke oven gas. The slabs

are carried on water-cooled skid pipes to the soaking hearth where the temperature is permitted to equalize and the skid marks removed. This hearth has been found to be absolutely necessary in the heating of this material. In the past, the great objection to its use was the excessive diiffculty and cost of maintenance. This has been eliminated by two features: Better control of the furnace atmosphere, so as to prevent sweating of the steel and the deposit of cinder on the hearth; or the creation of excessive scale and improved construction of the hearth itself.

The top 4½" of the hearth is usually constructed of a chrome ore mixture, which is allowed to stand in a monolithic mass, or of chrome brick laid so as to prevent kicking out. An important feature is the imbedding of heavy steel skid billets approximately 14"x3" in cross-section in the hearth itself. These do not extend above the level of the hearth, so that there is no danger of their welding to the slabs, yet they serve as riders which prevent the heavy slabs from digging out the hearth in a short space of time. Slab heating furnaces, which have heated 10,000 tons of slabs per furnace month when the individual slab weighed from 1500 lbs. to 4,000 lbs. have been operated continuously for from six to eight months without any major hearth repairs.

The general design of this furnace is particularly interesting, inasmuch as it embodies the successful adaptation of a number of important scientific theories. The unusually large combustion chamber with the vertical back wall provides a furnace volume for the completion of combustion above the steel. This is particularly desirable with the fuel used, as coke oven gas is only semi-luminous when burned as compared with producer gas. For this reason, the higher flame temperature obtainable may be utilized without danger of overheating the slabs at the discharge point. The greater space provided for combustion permits the gases to remain in the furnace a longer time than with a more luminous fuel with lower calorific value, and thus increases the efficiency. Furthermore, the depth of flame increases its luminosity and hence its radiant powers. This feature was definitely determined in experiments conducted by Professor Trinks and others and referred to in the second edition of his first volume on "Industrial Furnaces" published in 1926. It was established that doubling the flame depth of a semi-luminous flame increases its radiant powers by approximately 20%. As the heat transfer by radiation is based on the difference of the 4th powers of the temperatures of the body being heated and the flame, it is obvious that this increase in the availability of the heat is an important one.

A heat balance of the furnace under discussion indicated a thermal efficiency of approximately 40%, when operating continuously on cold steel. One of the contributing features to the efficiency obtained is the design of the burners. The gas is delivered through an alloy spud at approximately one pound pressure. It will be noted that the air is aspirated through the venturi-shaped refractory burner block. The air in the chamber at the burner blocks is under a positive pressure of from zero to two-tenths inches. This is controlled by the regulation of the dampers controlling the air entering the recuperator. Coke oven gas at a pound pressure does not possess sufficient kinetic energy to aspirate the total volume of air required for combustion. For this reason, approximately 10% of the total air required at each burner is injected through the concentric area formed by the outer pipe surrounding the gas nozzle. This serves a double purpose of providing sufficient air for complete combustion and also for aiding in controlling the condition of the flame with respect to the rate of flame propagation. The burners have also another adjustable feature which has an influence on the rate of flame propagation, but which will not be discussed at this time. It is interesting to note that since this installation was put in operation it has been demonstrated that the features added to the burners confirms the belief or opinion that the completely aspirating, or pre-mix, type of burner would not give a suitable flame condition for the efficient heating of steel to rolling temperatures in continuous furnaces of the type described.

FIG. 3.

Figure 3 is a photograph of the installation of three furnaces, as shown in cross-section in Figure 2. A furnace designed for the same purpose fired with producer gas has been in successful operation for three years. No under-firing is employed on this furnace however, although the water-cooled skids and soaking hearth are provided. Gas and air are fired through ports rather than burners, the air coming in above the gas at an angle of approximately 30°. The roof is somewhat lower and has a sloping contour as compared with the furnace shown in Figure 2. The recuperator on this furnace has one-pass, as the air temperature required to obtain the desired flame condition in the combustion chamber with producer gas of approximately 150 B.t.u. per cubic foot, and 900°F. temperature at the ports, is only 700° F.

This furnace operates continuously at a rate of approximately 70# per square foot of hearth area with an over-all monthly coal consumption including stand-by losses of 225# per gross ton of steel heated. It has been found that on this type of heating from 70 to 100# per square foot of effective hearth area is about the rate that may be expected when satisfactory results are to be obtained.

Figure 4 shows a large oil-fired slab heating furnace, employing the principle of the double burner arrangement, as shown in Figure 1.

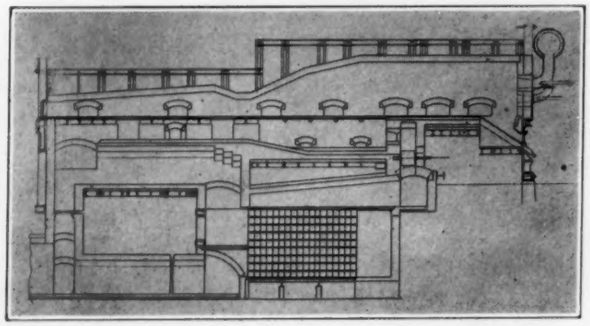

FIG. 4.

The application of insulation to high temperature reheating furnaces is a refinement which will unquestionably be applied to many more installations in the future. On one installation in a large Ohio plant, insulation applied to the roof of the furnace channel as far as the combustion chamber not only showed a saving in fuel consumption, when compared with a duplicate furnace, but also reduced refractory maintenance, due to slowing down the rate of cooling of the furnace refractories during week-end shutdowns.

The application of complete insulation to the combustion chamber has been carried out in a few instances, and reports indicate that the present-day first quality fire-brick will withstand the increased average heat to which they are subjected; however, this point has not yet been conclusively proved and where temperatures are in excess of 2400° F. insulation has not been universally adopted for furnace walls. It has been found that the most practical method of applying insulation to the walls of a continuous type of furnace is 4½" of insulating brick on the outside of 13½" of fire-brick. The insulating brick is held in place with ¼" steel plate. The additional net cost of this construction, as compared with the customary 18" furnace wall, is approximately 80c to 90c per square foot. Assuming an average furnace temperature of 2000° F., throughout the length of the furnace, this would represent a saving of approximately $1.00 per sq. ft. of wall surface per year, based on 100% operating time, and fuel valued at 20c per million B.t.u. It is safe to say that under normal operation this would represent at least a 50% investment.

A further means of effecting savings on such furnaces is by air-cooling both the roof and the side walls and employing the heated air for combustion at the burners. Such designs have been worked out, in complete detail, but at the present time the air cooling of the side walls has not been applied to an actual installation.

Soaking Pits:

Probably the outstanding development of the past two or three years has been the successful application of the Stein Patented Recuperative, or one-way-fired, Soaking Pit to American practice. As is now well-known, the basic feature of this pit is the method by which the heat is applied continuously through a port located above the ingots and removed through waste gas outlets close to the pit bottom at the same end. The flame travelling through the pit describes a horseshoe. Certain advantages gained over the customary reversing regenerative type of installation are obvious. Outstanding among these are: Less space, low first cost, better heating, fuel saving, and lower maintenance. This paper will discuss these advantages in the light of actual experience.

The first pit of this type was constructed as a trial proposition at the plant of the Donner Steel Company at Buffalo, New York, and was placed in operation February 27th 1927. There was one hole—5'-6" wide by 9'-6" long, by 9'-6" deep to top of coke braize. It was fired with coke oven gas and preheated air from a refractory tile recuperator. The pit was originally charged with six 21½" square ingots, but later in the year was lengthened to hold eight ingots. From the start, the fuel records indicated a considerable saving over the regenerative pits in the same plant. The heating was more uniform and the only limiting factor was the length of time required to bring cold ingots to a rolling temperature. The trial pit was enlarged to hold eight ingots during 1927. It was found that the minimum satisfactory heating time for eight ingots from cold to rolling temperature was approximately ten hours. This is equivalent to 105 lbs. of steel per square foot of hearth area per hour. This practice is quite suitable for alloy steel, but for ordinary steels it required a change in the port design, different from the experimental installation in order to reduce the heating time.

In 1927, the American Tube & Stamping Company, of Bridgeport, Connecticut, after inspecting the Donner experimental pit, ordered two batteries of two holes each to be fired with producer gas. These were placed in operation January 1st, 1928. On account of the different fuel used and kind of steel heated, it was necessary to use a pressure type of port in order to obtain proper flame distribution and capacity.

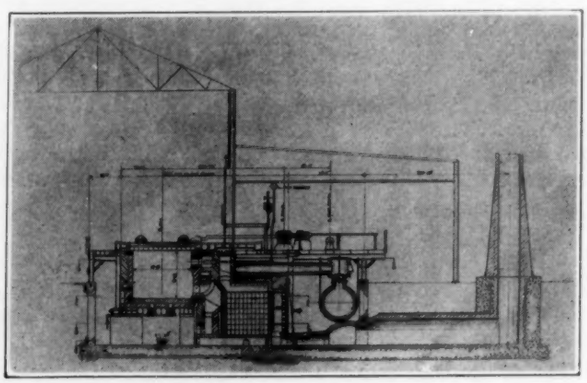

FIG. 5.

Figure 5 shows a cross-section through one hole of two 4-hole batteries constructed for the John A. Roebling's Sons Company, at Trenton, New Jersey, in 1929. This is the port which was applied to the Bridgeport installation early in 1928. It solved the problem of flame distribution and pressure control.

The essential feature is the employment of the general principles of the venturi, or aspirating, type of burner. The alloy venturi nozzle and cold air injection are employed with our refractory tile recuperator in order to obtain the necessary pressure. With the successful solution of the problems on the Bridgeport installation, the development of the use of the one-way pit proceeded at a very rapid rate, so that during the past year there were more new installations of this type built than of the reversing type. It has been found applicable to the heating of every kind of steel, including all degrees of carbon content, and special alloy steels. Alloy and high carbon steels are heated at the Donner and Central Alloy installations, and small quantities of steel having a carbon analysis of 0.04 carbon, requiring a temperature of 2400°, have been heated successfully at the installations employing our standard tile recuperator and also a metal preheater.

As the Roebling installation is typical of a producer-gas fired pit equipped with the Chapman-Stein Refractory Tile Recuperator, a further study will perhaps be of interest. Figure 5, mentioned above, shows clearly the method of introducing the gas and air at the ports and indicates the general arrangement of each hole.

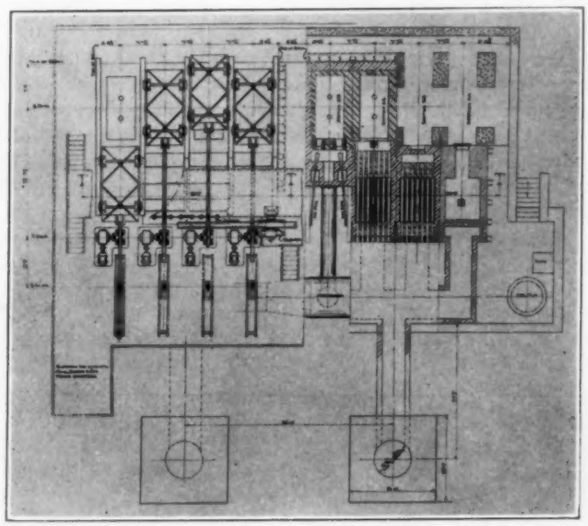

FIG. 6.

Figure 6 shows a plan view taken through various sections of each hole. The method in which the air is divided at the ports and the flow of the waste gases through the recuperator is clearly indicated. It will be noted that the recuperator tile are braced at each end by dividing walls. We generally term these "feather walls" or "brace walls." At the plug end of the recuperator these walls are laid up of first quality fire brick. At the end facing the waste gas outlets from the pit, they are laid up of special high temperature refractories. The tile themselves, although subjected to temperatures as high as 2400° F. in the top pass, suffer no danger from softening, due to the fact that they are being constantly cooled by the inflowing air for combustion. It was necessary, however, to find a brick of higher heat resisting qualities than the average run of fire brick to withstand the temperatures to which the feather walls at the pit end of the recuperator are subjected. The B & W #80 and "Lawtonite" have both given satisfaction in this point, and investigation of the installations in operation for over a year have indicated no tendency to spall, or fuse. It will be noted in Figure 5 that a slag pocket is provided for catching any slag which may possibly be carried over the waste gas outlet

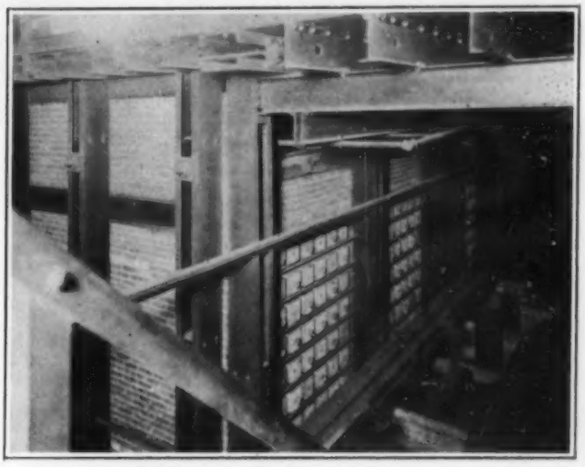

FIG. 7.

bridge wall of the pit, due to carelessness in caring for the bottom.

The recuperator waste gas passages may be easily blown out, and Figure 7 shows a photograph of the plug end of the recuperator. These plugs may be

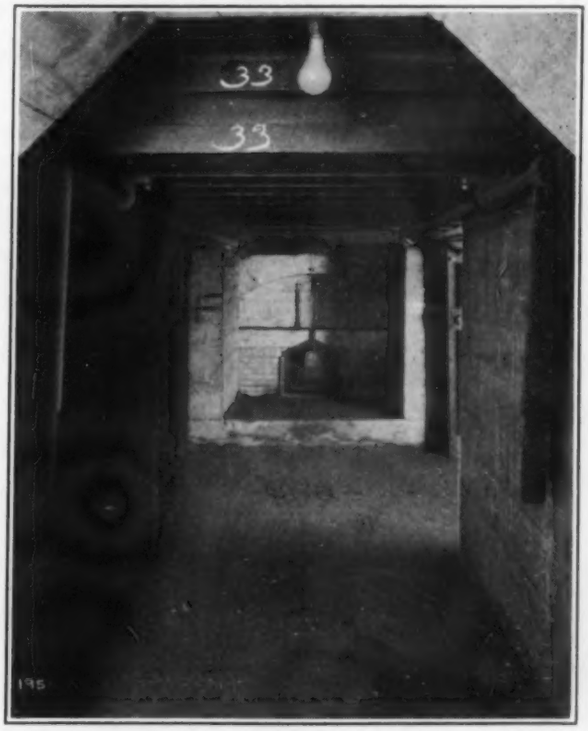

FIG. 8.

removed by hand for cleaning the tile passages. The experience on even producer gas fired installations, where there is naturally a greater ash or dust deposit

than with other fuels, has indicated that a few hours spent every six months suffices to keep the waste gas passages clear.

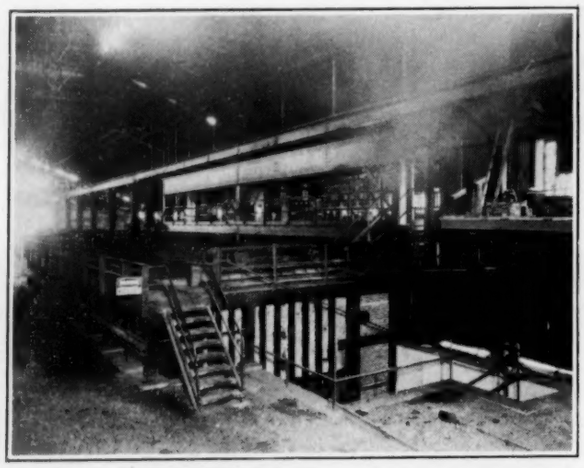

FIG. 9.

Figure 8 shows a picture taken underneath the pit. This shows the slag pocket bulkhead and the slide damper for controlling the amount of air taken into the recuperator. The lever arms moving the small buggies closing the slag holes at the bottom of the pit are also apparent. In all of our installations, we provide a complete control for each individual hole. On the installation described, the controls consist of three wheels located on a control board and means for regulating the fan air from the header to the individual hole. The three wheels control respectively the gas flow to the hole by regulating the mush-room valve, the air taken into the recuperator by regulation of the slide damper already shown, and the amount of stack draft by regulation of the pit stack damper, which is shown in Figure 5.

Figure 9 shows the entire installation of two 4-hole batteries with a control platform located in the

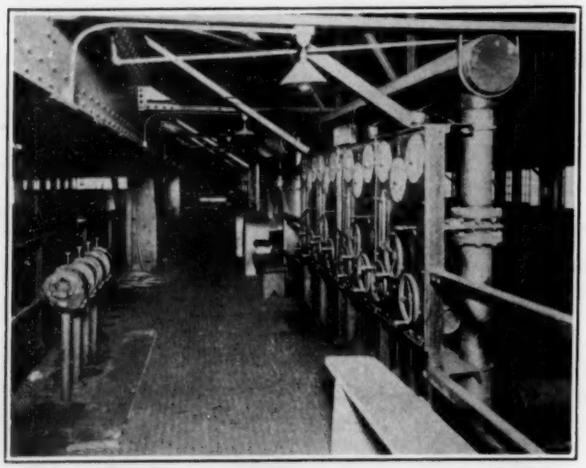

FIG. 10.

lean-to. Figure 10 shows the control platform with the devices just described clearly in evidence along with the cover operating control stations and the fans for providing the pressure air.

There has been considerable discussion of late years regarding the application of automatic control of combustion and temperature to pit furnaces. It is our belief that such control is not necessarily desirable, due to the diversity of steel heating conditions, which must be met from time to time, and also the varying condition of the temperature in each hole according to the temperature of steel charged. In each installation, we endeavor to provide the equipment necessary for the absolute control of the condition within the individual hole. In the case of

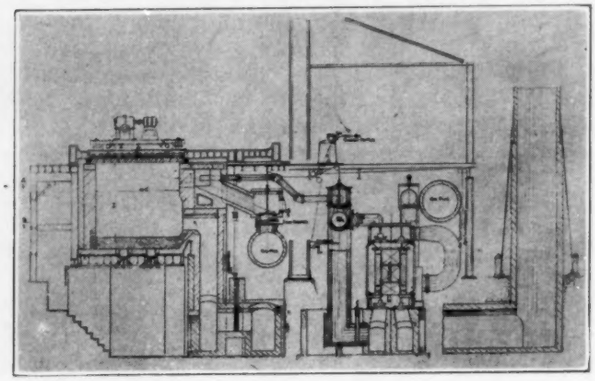

FIG. 11.

producer gas, it is advisable to employ a regulator, in order that the pressure on the up-stream side of the valve to the hole is always a constant factor. In a similar manner, the air should always be available under approximately the same conditions, and the stack draft sufficient to provide any condition necessary within the pit.

It is interesting to note that, on actual checks of this type of pit, the draft required at the waste gas outlets under normal operation is from 0.1″ to 0.3″ of water, depending upon the rate of firing. At the top of the pit, there is a slightly positive pressure of approximately 0.005″ to 0.01″.

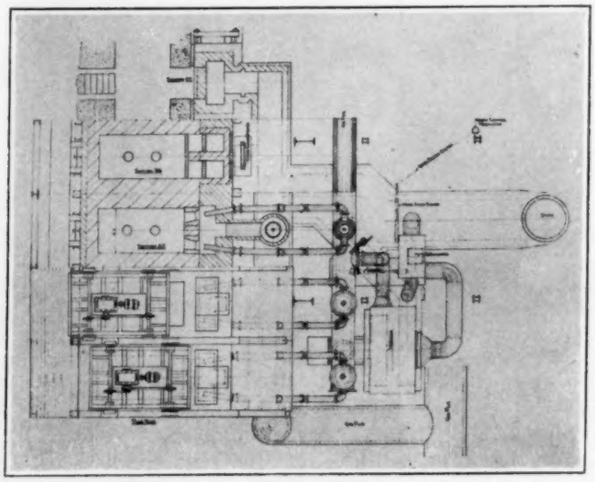

FIG. 12

With the control features taken care of, the actual heating operation is a comparatively simple matter, and the heater can easily obtain the type of combustion required for the analysis of steel that he is heating.

The successful operation of the one-way pit is independent of the method of preheating the air employed—as long as continuous flow of air for combustion to the ports is assured. The Blaw-Knox Preheater has been successfully applied to a number of our installations. Figures 11 and 12 show an elevation and plan section respectively of an installation of five holes equipped with one Blaw-Knox Preheater. This pit is fired with producer gas at about 900° F. temperature at the ports and the air for combustion is preheated to approximately 850° F.

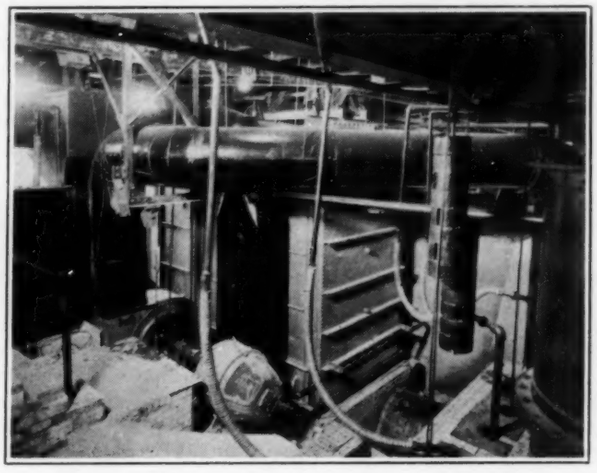

FIG. 13

Figure 13 shows a preheater installed in connection with a soaking pit. Due to the fact that the outlet gases from a pit are often above the maximum temperature of 1800°, which the heating elements in the preheater will with-stand, a number of safety devices must be provided to protect the pre-heater. Quite often the waste gases leaving the pits contain combustible gases, which is somewhat governed by the particular heating requirements, as mentioned heretofore. For this reason, provision is made to bleed air into the waste gas flues to insure complete combustion of the gases before entering the preheater. The gases passing through the preheater are diluted by re-circulation of a portion of the waste gases delivered from the exhaust fan to the stack whenever the inlet temperature rises above a certain point. This re-circulation is controlled by a metal expansion member, which in its linear expansion operates the mechanism controlling the re-circulating valve. An automatic control or fusible link is also provided for shutting off the flow of gases to the preheater when the temperature exceeds 1800° F.

It is obvious that on such an installation as the one shown the shutting down of several holes for soaking would materially increase the draft on the remaining holes and necessitate an adjustment of their individual dampers. To provide for this feature, a Hagan Automatic Draft Regulator is installed which operates the main stack damper in order to maintain a constant draft at all times. In a similar fashion, the pressure of the air for combustion in the header adjacent to the individual air control valves is maintained constant by a Hagan Regulator, which actuates a butterfly valve located between the air fan and the preheater. Inasmuch as a reduction in the supply of air through the preheater would cause a rise in the air temperature unless the supply of waste gases were reduced correspondingly we provide a ratio controller. This ratio controller actuates a butterfly installed on the discharge side of the exhaust fan, extracting the waste gases from the preheater, and at the same time actuates the butterfly valve installed in the cold air supply pipe to the preheater. Although the metal preheater will give a greater rate of heat transfer than the tile recuperator, it possesses no advantage from this standpoint, inasmuch as the waste gases may be taken into the recuperator directly form the pit at a much higher temperature and consequently compensate for lower rate of heat transfer. Air preheat temperatures as high as 1700° F. have been obtained with tile recuperators installed in connection with soaking pits.

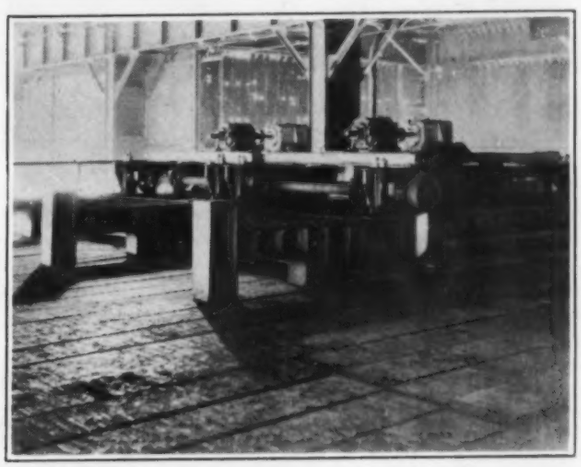

FIG. 14.

Figure 14 shows a cover suspended from a truck, on which the driving mechanism is mounted. The development and refinement of this design has still further enhanced the possibilities of increasing pit capacities with the installation of the one-way type of pit. It will be noted that the cover itself is suspended from hangers independent of the truck, which can be run off the cover under its own powers when repairs are required. In this manner, a new cover may be substituted with a minimum of delay.

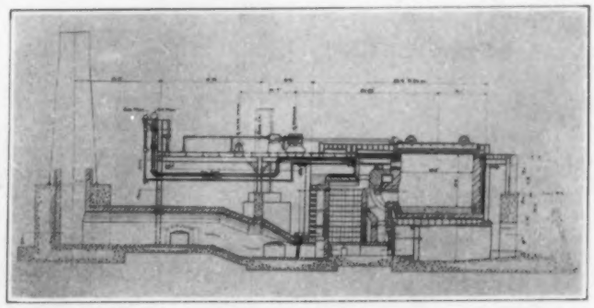

FIG. 15

Figure 15 shows a cross-section through one hole of a 7-hole battery constructed for The Corrigan, McKinney Steel Company, at Cleveland, Ohio. This installation is equipped with refractory recuperators,

and is fired with coke oven gas. It will be noted that the pressure of the gas is used to partially aspirate the air for combustion. As the kinetic energy of the gas is not sufficient at all times to aspirate all the air for combustion under the conditions required, a small amount of fan air is introduced concentrically around the gas. This is always less than 10% of the total air required for combustion and the resultant air temperature compensated for by a slight increase in the recuperator size.

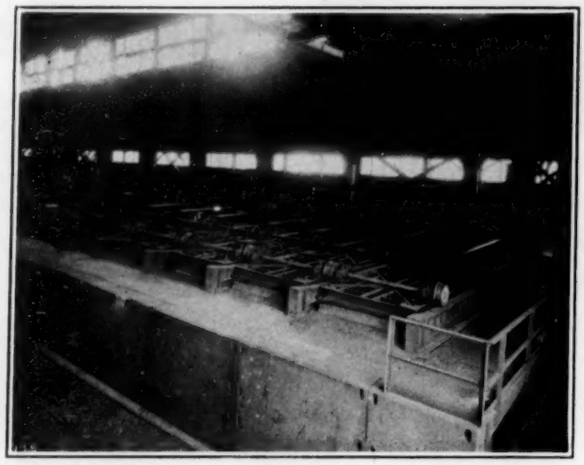

FIG. 16.

Figure 16 is a picture of this installation and is particularly interesting from the construction standpoint inasmuch as seven holes have been successfully tied in together, because of space limitations. The control boards and fans are shown in the background.

Former checks on the fuel consumption of the one-way-fired pit, as compared with the regenerative type in the same plant, have indicated a saving of approximately 20% to 25% in fuel required per ton of steel heated. These records which were obtained at the Donner plant in 1928 have been confirmed by results obtained on other coke oven gas fired installations within the past few months.

Figure 17 is a curve based on the B.t.u. required per ton of ingots heated on two separate installations. The various heating rates are expressed in pounds per square foot of hearth per hour. The ordinate represents the heating rate and the abcissa the fuel rate per ton. Each point represents the average fuel rate per ton for a 24-hour period, and the heating rate is based on the average hourly tonnage heated over the same period divided by the total hearth area. Unfortunately, these records were obtained during recent months when both of the plants were running below their normal capacity due to lack of business. For this reason, the highest average heating rate shown on the curve is approximately 138 pounds per square foot of hearth area per hour, or approximately 5.2 gross tons per hole hour. The maximum capacity for continuous heating in a hole

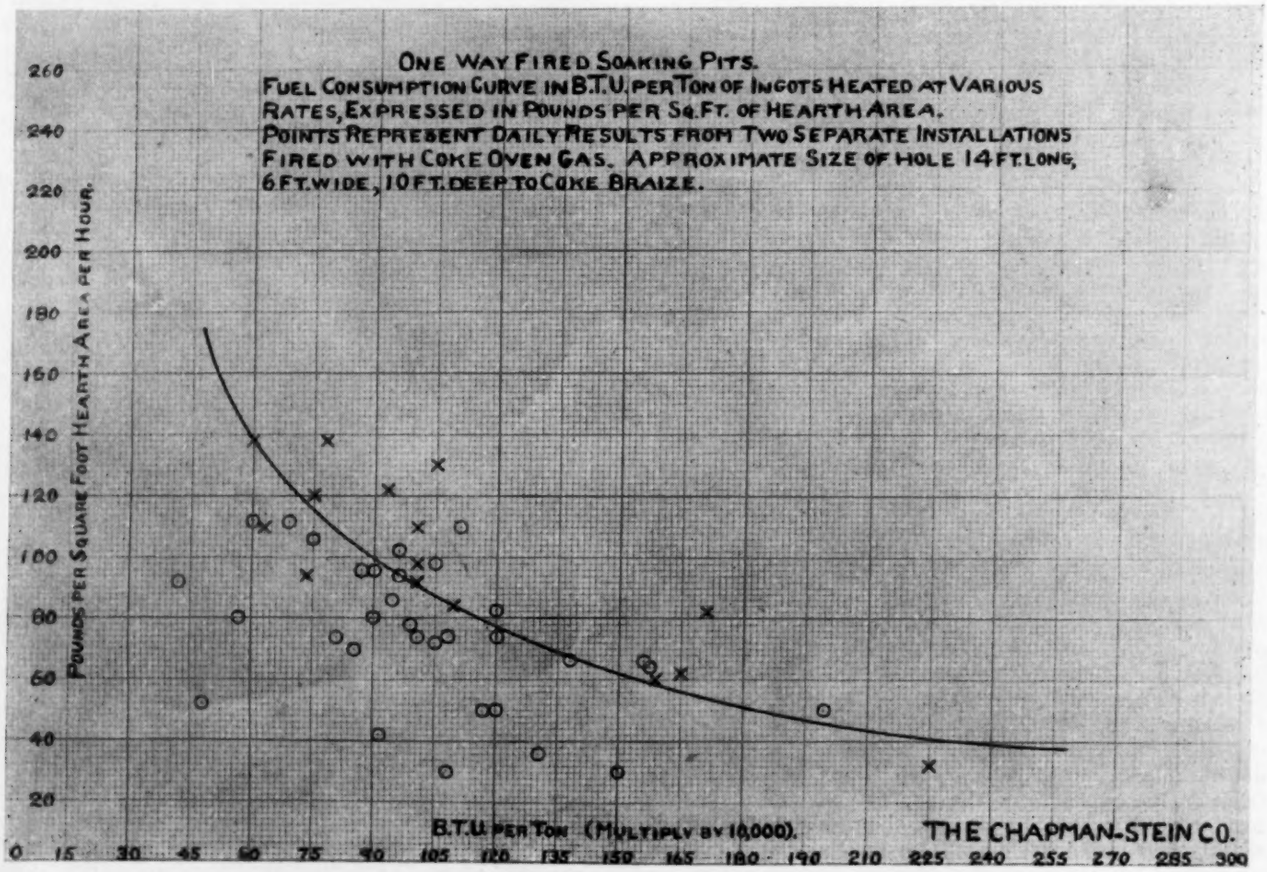
ONE WAY FIRED SOAKING PITS.
FUEL CONSUMPTION CURVE IN B.T.U. PER TON OF INGOTS HEATED AT VARIOUS RATES, EXPRESSED IN POUNDS PER SQ. FT. OF HEARTH AREA.
POINTS REPRESENT DAILY RESULTS FROM TWO SEPARATE INSTALLATIONS FIRED WITH COKE OVEN GAS. APPROXIMATE SIZE OF HOLE 14 FT. LONG, 6 FT. WIDE, 10 FT. DEEP TO COKE BRAIZE.
POUNDS PER SQUARE FOOT HEARTH AREA PER HOUR.
260
240
220
200
180
160
140
120
100
80
60
40
20
0 15 30 45 60 75 90 105 120 135 150 165 180 190 210 225 240 255 270 285 300
B.T.U. PER TON (MULTIPLY BY 10,000).
THE CHAPMAN-STEIN CO.

FIG. 17

14'-0" long by 6'-0" wide is approximately 133 pounds per square foot of hearth area, or five tons per hole hour, when heating cold steel. When heating hot steel from the Open Hearth, the capacity is approximately 500 pounds per square foot of hearth area per hour, or 18.8 tons per hole hour. These rates can only be reached in actual practice, of course, on an individual charge, as the average tonnage over a turn, or a day, must take into consideration the time lost in charging and discharging, waiting on the mill, etc.

One of the important factors which contribute to the efficiency of the one-way type of pit is the fact that the waste gas outlets and the firing ports are entirely separate. This makes it possible to design a firing port for efficient and economical combustion of the fuel used. In the old style regenerative pit the port must ordinarily be a compromise in order to serve the two functions of acting both as an outlet and an inlet port. It is apparent that this item will also have an important bearing on pit maintenance.

The combustion space provided above the steel is, of course, of great value in promoting efficient use of the fuel, and the more extended travel of the flame within the pit renders it more availbale for heating than in the regenerative type. Furthermore, there is no tendency for the gases to channel and cause uneven heating. As efficient combustion is provided for at the port, free oxygen in the waste gases which would cause excess scaling is reduced or eliminated. The compromise port construction and the channeling of the gases already described often makes this a source of difficulty in regenerative pits.

The fact that a continuous flow of fuel is provided is another important feature. The fuel loss, which occurs when reversal takes place in the regenerative pit, is completely eliminated.

Due to the more efficient port construction in the one-way fired pit, it is possible to operate closer to the theoretical air required for a given fuel. For this reason it is conducive to low scale loss.

Another interesting feature borne out by actual results is the fact that, although on comparable size installations of recuperative and reversing pits we have found that the weight of the checker brick is approximately 200% of the weight of the recuperator tile and feather walls, it is possible to hold steel ready for rolling in the recuperative pit longer than in the reversing type. In one plant the heaters reported that they could hold steel for approximately two hours in the reversing pits and three and one-half to four hours in the recuperative pits. This feature does not, of course, apply where the metal preheater is used, as no stored heat is available when the pit is shut down with such an installation except the heat in the pit walls themselves. However, definite results have established the fact that the steel may be held approximately two hours in the one-way-fired pit equipped with the metal preheater.

Due to greater refractory mass for heat storage in the regenerative pits, the results just cited are rather surprising; however, it should be remembered that the top pass of the tile are at approximately the outgoing temperature of the waste gases from the pit, say 2100° to 2300° F. On the other hand, the checkers on the firing side of a reversing pit will be at from 1400° to 1800° F., depending on the length of the period between reversals. It is obvious, therefore, that heat will be radiated from the steel and pit walls to the cooler checker chamber until all is at reduced temperature equilibrium. In the case of the recuperator, the refractories—being already at the pit temperature—will aid in maintaining that temperature through the increased heat storage present. There are, of course, less radiation losses from the recuperator as compared with the checker chambers due to the reduction in the numbers of exposed sides.

Bottom making is always a necessary evil in the operation of soaking pits. It will be observed that the usual practice in our pits is to employ a coke braize bottom of from 12" to 18" depth. The plants where the one-way installations are in use report that the making of bottom is no more difficult than in their present regenerative pits. The fact that the waste gas outlet is located at one end makes it easier for the bottom-maker to work to work, as the heat can be drawn away more easily from the top of the pit. No cinder is made, and the scale is minimum—less than 2%. The thickness of the scale on several charges which were measured was approximately 1/16".

The authors regrets that time and space do not permit the discussion of many other features which we believe would be of interest in this paper. The question of mixed fuels has not been touched upon at all, though considerable work has been done along this line in recent years. It is obvious that the one-way type of pit lends itself to an efficient use of mixed fuels due to the divorce of the firing ports from the waste gas outlets.

In closing, I would like to refer again to the subject touched in the opening paragraphs of this paper, namely, the importance of heating in the cost of steel conversion. It appears to me that this may be divided into two headings: Quality of heating, which affects steel conversion cost from the standpoint of finished product, power cost, yield, and mill maintenance; and the direct cost of heating, which is effected by fuel consumption, production, maintenance, and labor costs.

It would appear from the results obtained that during the past few years the improvement in furnace design and construction has done much to improve the two factors mentioned.

Hot Metal Handling

By Walter de Fries*

If it had been the good fortune of the steel-making process to emerge from a modern laboratory as the result of systematic research in applied metallurgy, the need for a discussion of hot metal handling practice would probably not exist, because steel production would have been developed as a continuous process in an apparatus resembling the well known American production line.

Since steel was made, however, long before modern chemistry arrived as a creative force, its basic production methods are still the same as those followed by the artisans and craftsmen of the last centuries except, of course, on a vastly enlarged scale, made possible by the developments of our machine age.

Consequently, a two-step process instead of a continuous production method is still the accepted practice in the making of steel, with iron smelted from iron ore in the blast furnace as the intermediate product.

The handling of such "iron" is the subject of this discussion; when released from the blast furnace as "hot metal" in a liquid state, it was originally cast into a sand bed and allowed to solidify in the form of triangular bars, to be subsequently broken into shorter sections for convenient handling by human labor. Blast furnace iron as such, however, has little demand as a final product, and consequently had to be remelted again for further refining either through a cupola for foundry purposes or by means of the Bessemer or Open Hearth process for the production of steel.

Obviously it was an economic waste to allow blast furnace iron to cool off merely for the purpose of transportation and then bring it back into the liquid state for further processing steps at a corresponding expense for fuel, so ladles were introduced as a means for carrying hot metal from the producing blast furnace to the consuming refining station in liquid form where the location of these two plant units was in close proximity. Where larger distances separate the blast furnace from the consuming plant solidifying of iron by means of "pig casting" machines has supplanted the sand bed casting method almost entirely.

Iron ladles were fashioned in the shape of a bucket of sufficient volume to hold from 20 to 40 gross tons of hot metal (110 to 220 cu. ft.) and consisted of a steel shell with a refractory lining of sufficient thickness to protect the former from the heat of and contact with their hot liquid contents.

Conceived merely as carrier vessels, no thought was given in their design to other requirements of the hot metal handling situation, originating from the fact that the refining processes are intermittent in their operation and not continuous and require time intervals different from those prevailing for the casting of a blast furnace, usually attended to in periods of from four to six hours. It is, therefore, not always possible to coordinate the time of tapping a blast furnace with the requirements of the refining process so as to avoid an intermediate holding or storage of hot metal, particularly in large works with a number of iron producing and processing plant units. Furthermore, blast furnace operation, as above stated, is still an art, rather than a science, and the resultant product, while fairly uniform in modern practice, was, and still is, not always of the most suitable analysis for the requirements of the refining processes.

To meet these exigencies, storage vessels of sufficient capacity to hold several casts were introduced, in the form of hot metal mixers, as a convenience for the temporary disposal of hot metal and its preliminary conditioning when "off-cast" through mixing with larger quantities of "regular" iron. Such mixers serve as equalizers between supply and demand of hot metal, and due to the substantial reduction in ratio of heat radiating or dissipating surface to iron holding capacity typical of their construction as against that of the ordinary bucket type ladles, in the capacities above stated, they are able to keep iron in liquid condition for extended periods without the aid of a separate fuel supply.

The economic justification for a mixer installation rested, therefore, further in its ability to reduce partial freezing or solidification of hot metal in the ladles which received it from the blast furnace, with the resultant reduction in their holding capacity through such formation of "skulls" and in the expenditures necessary for removing and remelting of such skulls.

On the other hand passage of iron through a mixer requires not only a considerable investment but causes also continuous maintenance and operating expense with losses of iron due to its repouring in and out of this intermediate storage facility. Considered a convenience as permitting two of more processing departments to work independently of each other in their schedules, which may thus be timed to suit individual operating characteristics, a mixer installation is nevertheless another step away from that most desirable of all operating practices—continuous.

Accordingly larger ladles of the bucket type came into use in recent years, which of course had also a lower ratio of radiating surface to cubical contents and thus a smaller heat loss; iron could be held in such ladles for about one hour with but slight skulling and these containers were particularly adapted to steel works, where they were shifted to the Open Hearth Department for direct discharge into the furnaces. For merchant furnaces making foundry iron to be cast into "pigs" or Bessemer steel plants, where iron is processed in lots of from ten to twenty-five tons and must be, therefore, reladled in such quantities, the so-called mixer type ladle, developed during and since the World War, proved itself advantageous. Such units are constructed with barrel type containers resembling conical mills and are distinguished from the bucket type ladle by the absence of an open top, the source of greatest heat loss in the older type container; built in capacities

*Chief Engr., The William B. Pollock Co., Youngstown, O.

up to 150 tons to take an entire cast from a medium sized blast furnace, such ladles are lined in mixer fashion with a suitable refractory material to a thickness about 75% heavier than customary with open type ladles and thus become heat retaining to a point, where iron can be stored in them for extended periods without marked skulling or freezing, just as in a mixer. They carry their own tilting mechanism and may therefore be discharged independent of auxiliary handling equipment, with the "barrel" or ladle forming the connecting link between the car trucks, so that it cannot be lifted for overhead handling.

Their economic advantage originates from a very substantial reduction in iron loss, due to diminished skulling, when compared with the older style ladle of small capacity and they have made long distance handling of hot metal possible, thereby introducing a departure from the old practice of solidifying iron, previous to shipment beyond the limits of the producing plant.

Their limitation rests with their design of ladle and car as an inseparable unit, requiring repouring of iron just as with the mixer, for disposal of their contents, a step, which as above pointed out, should be avoided for steel plants, where hot metals in 50 to 80 ton lots is required for refining by the open hearth process.

To meet the requirements in steel mills for direct handling of hot metal, as the ideal way, there was thus need for an iron carrier large enough to hold an average hot metal charge for an individual open hearth furnace and of the heat retaining type to permit storage of iron for reasonable periods in transit on tracks between blast furnace and open hearth departments, thus eliminating storage through a mixer, and further designed for overhead handling of the iron holding vessel, so that it may be lifted from its carriage and emptied directly into the furnace without repouring through a transfer ladle. Equipment of this type has the further advantage of permitting selection of iron according to individual ladle analysis to best suit the specifications of the steel to be made in the open hearth heat, for which it would be selected.

All of these demands are met by a ladle design employing a spherical shape, as nearly as practicable for construction purposes. As is well known the sphere as a geometrical body has the smallest ratio of surface to volume and thus is the most logical shape for a container, whose purpose is to preserve the heat of its hot metal contents, by restricting radiation losses to the very minimum; lined, as most hot metal mixers, with a refractory of somewhat lower heat conductivity than ordinary fireclay brick, and to a thickness correspondingly less than customary with that in vogue on the mixer type cars above referred to, it has a top opening for charging and discharging, just sufficiently large to permit loading of unwieldy scrap into its hold such as ingot moulds, runner scrap, etc., all of which is converted into hot metal in this ladle by merely pouring iron from the blast-furnace-cast over it; this practice saves breaking of such scrap under the skull cracker for open hearth or Bessemer charging and the delay in the time of heats and fuel expense due to the necessity of melting such cold iron; equipped with trunnions for handling by overhead crane in the same manner as the bucket type ladle, these containers may be bodily lifted from their carriages and emptied direct into an open hearth furnace, for instance as late as ten to twelve hours after they have been filled with iron, and plants practicing hot metal handling in this fashion show, therefore, not only low iron loss but remarkably low fuel rates in open hearth practice as well.

Steel works enforcing a week-end shut-down in their open hearth and Bessemer departments will of course still need mixers for "Sunday-iron." The handling of such accumulation involves two re-pourings from mixer to transfer ladle and from transfer ladle to open hearth, while facilities for lifting the iron ladle and emptying it directly into the mixer eliminate at least two more. However, only one-seventh of the weekly iron production need to be handled in this detour manner, leaving six-sevenths for straight line passage between producing and consuming departments as pointed out above.

Spherical ladles, due to their design characteristics already referred to, require considerably less lining material and this can be installed in a vertical direction without the use of forms or special shapes. Its installation cost, when compared with that required for mixer type ladles of corresponding capacity, is only about one-third to one-quarter, and its useful life longer.

Handling hot metal in a container of this type has the further advantage of reducing dead load in transportation and lifting, a factor, which is of importance for existing plants where trestles, bridges and standard rails of 85# of 90# weight per yard limit the wheel-load of transportation facilities. To further meet such existing conditions welded steel construction has been resorted to as another advantage contributing to a reduction in handling of dead weight.

So much about modern equipment for the handling of hot metal; as to practice, certain features have to be considered also, if smooth operation with a minimum of maintenance expense is to be obtained. One of the requirements, which is of prime importance in changing from small capacity bucket type ladles to modern containers of the heat retaining type, as above described, is the abandonment of sand lined iron runners in the cast house. Where sand is allowed to float with the iron at casting time into a modern ladle it fuses, like in a glass furnace, and forms a viscous mass gathering up in it all graphite and kish; where exposed to cooling, as for instance at the spout of the ladle, it forms solid rim skulls, interfering with the easy discharge of the ladle and causing needless operating expense for labor required in its removal. Clay or brick lined runners are, therefore, necessary where modern ladles are to be operated with success and a minimum iron loss.

Another contamination of iron with coke dust, customarily spread over the hot metal in open top ladles as a protection against rapid cooling, must be abandoned in ladles of the heat retaining type as injurious to the lining not only for the ladle but that of mixers, converters and open hearth furnaces as well.

Generally speaking, therefore, utmost cleanliness of passages and containers through which iron has

to be handled, and their construction of refractory material not subject to rapid fusion on contact with hot metal is the best practice, and in this connection it should not be forgotten that each repouring of iron causes a lot of unavoidable but undesirable kish formation with resultant iron loss.

Restriction of repouring is, therefore, desirable as a factor in lowering production costs and improving plant cleanliness, generally recognized a scontributing to a lower accident rate.

The modern hot metal ladle of the heat retaining type, in capacities large enough to meet the required hot metal charge for the open hearth furnace, and placed demountably on a welded steel car is to date the only equipment, which makes steel production continuous in spite of an intermittent start and finish. It receives its charge, stores it until needed and discharges it only once for final disposition, thus saving labor and reducing investment as well as operating costs to a degree, which may fittingly be termed the unavoidable minimum with present day production methods of steel.

Economical Combustion

By W. P. Chandler, Jr.*

The economical use of fuel in industrial furnaces means the accomplishment of the heating operation so as to produce as nearly a perfect product as possible with the use of the least quantity of fuel. Low fuel consumption requires the minimizing of all losses. The largest individual loss in any furnace system is due to the heat in the waste gases. One of the simplest methods of reducing this loss is to return to the furnace, in the form of pre-heat in the air for combustion, heat which would otherwise pass up to the stack.

For a given operation two things are necessary so far as application of fuel is concerned. First, the delivery to the furnace of sufficient total heat for the heating operation; and jointly with this, the location and distribution of temperature within the furnace so as to produce the desired results.

Two separate problems are therefore involved, each directly related to the other. As regards the delivery of the required amount of heat to the furnace, it is perfectly obvious that the more heat delivered in the form of sensible heat in the preheated air, the less must be supplied as calorific heat in the fuel. Therefore the degree of preheat in the air bears a direct relation to fuel economy and maximum preheat can not be sacrificed without detriment to fuel economy. The second problem is a matter of designing the furnace and burners so that the total amount of heat can best be utilized in the particular heating process.

In most cases the furnace and burners should be so designed that the velocity of the air and gas stream can be regulated and the intimacy of the mixture controlled so as to develop the desired maximum temperature at the desired position in the furnace with a gradual diminishing temperature thereafter.

In virtually all steel mill heating furnaces it is possible to obtain a higher degree of air preheat than is necessary to develop the desired maximum flame temperature, particularly in view of the fact that the wide latitude available in burner design makes possible any desired intimacy of contact between air and fuel. Satisfactory operation therefore requires that the maximum obtainable flame temperatures be so modified through design of the burners that the distribution of the total heat supplied to the furnace develops the desired temperature distribution throughout the heating chambers.

It is a fallacy, therefore to secure economy by not returning all possible sensible heat to the furnace in the form of preheated air through fear of obtaining too high a flame temperature, due to limitation of existing furnace or burner design.

In spite of the self-evident gain in economy incident to the use of higher air preheats, there is a great difference of opinion as to the amount of air preheat which can be used for certain furnaces. This difference results in the wide variations in practice noticed in different plants. Some engineers or operators claim that 500° F. to 600° F. is all that can safely be used for continuous steel heating furnaces, and justify their opinion by the statement that higher temperatures have been tried with detrimental effect

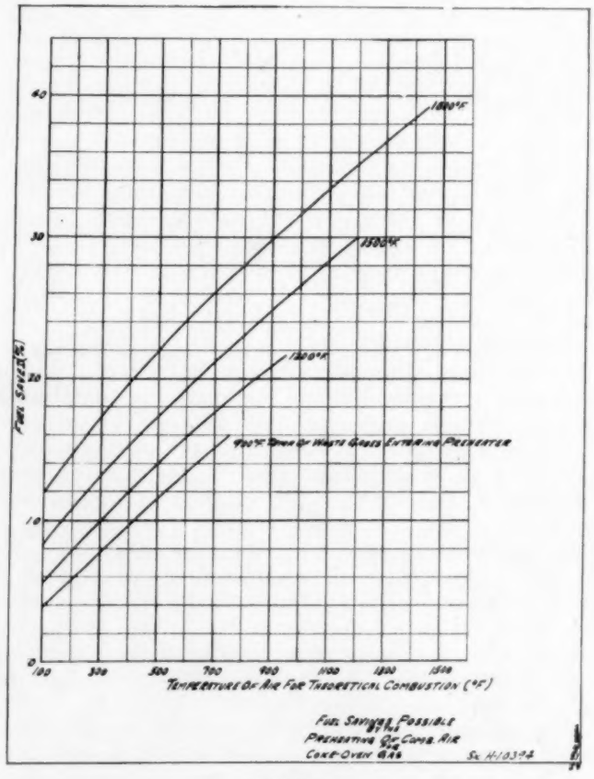

FIG. 1.

*Chief Engr., Furnace Equipment Dept., Blaw-Knox Company, Pittsburgh, Penna.

to the steel being heated. Other plants having continuous furnaces are heating the same character of steel satisfactorily with 1000° air preheat. The different results obtained at different plants simply signifies a difference in operation or design of various parts of the furnace.

The accompanying chart, Fig. 1, is given to show the real advantages to be obtained by preheating the air for combustion to as high a point as possible. The fuel considered in preparing the chart was coke oven gas, but comparable savings are obtained no matter what fuel is used. Four curves are shown, with the temperature of the waste gases leaving the furnace at 1800° F. in one case and at 1500° F., 1200° F. and 900° F. The percent fuel saving is calculated for the preheated air condition as against cold air. It will be noted for instance that with 1800° waste gas temperature a saving of 22% can be effected with air preheated to 500° F., but that 32% can be saved with air at 1000° F. In other words, the increased air temperature means nearly a 50% greater saving, and this additional air preheat can usually be accomplished with only a slight increase in investment. It is evident therefore that the most economical combustion necessitates the use of the highest preheat.

Let us consider a continuous billet or slab heating furnace as a typical combustion unit in the steel industry. In such a furnace, when operated at a normal rate of heating, the temperature of the products of combustion reach a peak a few feet from the burner block, gradually tapering from this point to the exit gas temperature. If the furnace is operating satisfactorily, the peak temperature will not cause any damage to the steel or brick work and will still be high enough to allow a fast rate of heat transfer from the gases to the steel to be heated. Assuming that the amount of air for combustion is properly regulated the two main factors controlling the speed of combustion and therefore the peak temperature are intimacy of mixing of air and gas and the temperature of the mixtures.

Furnaces constructed thirty or forty years ago were usually equipped with burners consisting of a piece of pipe extending through slots in the front wall of the furnace. The air was aspirated from the atmosphere or sucked into the furnace by excessive draft within the furnace. No premixing or preheating was obtained and the slow mixing within the furnace resulted in a long smoky flame and high exit gas temperatures. The development through the intervening years has produced the different means for preheating the air and for properly burning the gas. The development has now reached a point where furnace temperature must be controlled in order to secure the best results in furnace operation. For maximum economy the furnace designer must provide for maximum air temperature and in order to secure the best results must then provide means for controlling the temperature by adjustments at the burners.

In order to point out the different character of flames which may be produced by varying the intimacy of mixing and the degree of preheat, the accompanying diagrammatic sketch, Fig. 2, has been prepared. Intimate mixing of air and gas increases the rate of flame propagation and consequently shortens the flame and increases the peak temperature since with the shorter time, the radiation of heat from the flame during formation is reduced. A similar result is produced by increasing the temperature of the air and gas mixture prior to ignition.

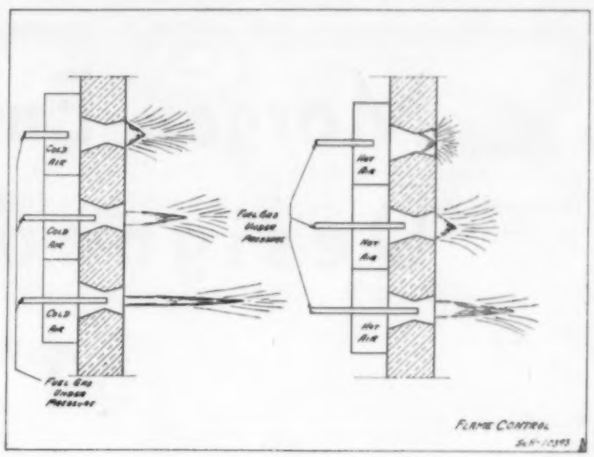

FIG. 2.

Many furnaces using cold air have had their operation materially improved by the application of preheated air, while others have been improved by the use of well designed burners. Combinations of both improvements show the best results and the maximum economy is reached in the case of the highest air preheat which corresponds to the lowest stack temperature. In the design of some furnaces the economy resulting from reclaiming part of the waste heat in the stack gases has been neglected, and an attempt made to improve fuel economy by premixing fuel and air to a maximum degree. When it is desired to secure maximum fuel economy with such a furnace, by reclaiming heat from the waste gases through preheating the air for combustion, it is necessary to maintain temperature conditions throughout the furnace similar to those previously existing. Such temperature control within the furnace is dependent on the burner equipment and requires means for properly regulating the degree of mixing within such equipment, the discharge velocity and the shape of the fuel and air stream. The burner equipment necessary to accomplish this result is one in which both air and fuel are under complete control as to point of mixing and relative volumes, such as various types of mechanically adjustable burners using air under pressure as supplied by a fan. The design of the discharge nozzle of the burner or the burner block must be such that the gas air stream maintains its form within the furnace, allowing the gas and air to intermingle thus insuring complete combustion. For the maintenance of the proper temperature condition across the furnace and prevent localized overheating a multiplicity of burners is advantageous.

Operators and engineers should give careful consideration to the maintenance of maximum economy in furnace operation through the use of maximum air preheat and should provide means for controlling the temperature conditions within the furnace through proper burner equipment.

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